A39

The Kent Incorporated Society for Promoting Experiments in Horticulture

ANNUAL REPORT 1955

EAST MALLING RESEARCH STATION

Near MAIDSTONE

KENT

1st October, 1954 to 30th September, 1955

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THE KENT INCORPORATED SOCIETY
FOR PROMOTING EXPERIMENTS IN
HORTICULTURE

ANNUAL REPORT

(FORTY-THIRD YEAR)

1955

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RESEARCH STATION

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H. Crittenden (32).
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(*Appointed October*, 1955.)

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All visitors wishing to see the work of the Station should go to the Reception Room in the N.F.U. Building at the Research Laboratories.

Visitors coming by road should take the turning to East Malling, opposite " The Bull ", Larkfield, on the main London-Maidstone road. The entrance gate to the Research Station is on the left, opposite the " King and Queen " in East Malling.

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Accommodated East Malling Research Station

Telephone : West Malling 2418.

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Clerical Assistant : Mrs. D. Nye. (*Part-time.*)

DR H. WORMALD.

[*face page 15*

DR. H. WORMALD

(1879-1955)

HARRY WORMALD, D.Sc., A.R.C.S., D.I.C., first Head of the Plant Pathology Section and sometime Assistant Director of East Malling Research Station, died at the age of 76 at his Maidstone home on Saturday, 10th December, 1955, after an illness of some years' duration.

Born a Yorkshireman in the village of Lofthouse, educated at the village school, and then at Lancastrian Grammar School, Wakefield, Wormald trained as a teacher from 1898 to 1900 at St. John's College, York, and then for eight years taught a general curriculum at schools in Bradford and Leeds. It was during this teaching period that his first and dominant love of field botany came to fruition, and in 1908, at age 30, he entered the Royal College of Science, Imperial College of Science and Technology, with a Board of Education scholarship, as a second-year botany student under Professor J. B. Farmer. Here his contemporaries included Cyril West and William Nowell, later also to become distinguished in the field of Economic Botany, as it was then termed, and with whom he always maintained touch. Three years later he was awarded a 1st Class Associateship of the College and graduated in London University with 2nd class honours in botany. In 1911 he started research at the R.C.S. under a Marshall Scholarship and was awarded the College Diploma. Later that year he went to Wye College in Kent as assistant in the Botany (Mycology) Department, and it was here, under the distinguished leadership of E. S. Salmon, that Wormald embarked on his well known researches on fungal and bacterial diseases of fruit and hops, and in particular on the Brown Rot diseases of fruit trees, a field in which he was later to become an authority of international repute. In 1916 he was awarded his master's degree on a study of the Celery-rot Bacillus, and in 1919 a doctorate on his early Brown Rot publications.

Between whiles Wormald found time to indulge his love of pure botany in studies such as the variation of the wild hop, but his interest at this time in copper fungicides against fruit diseases may not have been wholly unrelated to his marriage in 1918 to Miss L. K. Dudman, then a member of the Chemistry Department under Dr. Vargas Eyre and with whom he published jointly on the subject. Of this marriage two sons were born ; David, now a successful tea-planter in India, and John, a scholar of King's, Cambridge and now lecturer in physics in the University of Liverpool.

It was at Wye that Wormald came to know R. G. Hatton before the latter went to take charge of the new fruit sub-station of the College at East Malling. Thus from its inception Wormald was closely associated with this Research Station and its illustrious second Director, and was participating in its work, more particularly at that time in his studies of bacterial Crown Gall and the Brown Rot diseases, and in 1923 he transferred entirely to East Malling as first head of the newly formed Mycology and Bacteriology (later Plant Pathology) Section. In the same year the present writer joined him, also from the R.C.S., as the first of many research students and colleagues.

Wormald's career from this point as a pioneer in the annals of the then emergent applied science of plant pathology, and in particular of the pathology of fruit and hops, is well known in spite of his genius for escaping the public eye and getting on with his researches. Certainly his great energy and effective drive in research were matched only by his ingenuity in avoiding such distracting influences, so that it is not so much in ' *Who's who* ', as in the truly monumental corpus of his published research that the essential ' Myco ', as he was affectionately dubbed by his elder colleagues, is to be found. To borrow a phrase recently used of him, ' he would go to any lengths to avoid the limelight ' and get back to his beloved fungi, bacteria and plants. Nevertheless he was not allowed to escape high office altogether. In 1932 he became a recognized teacher of the University of London in plant pathology, and in 1936 he was appointed Assistant Director of the Station in succession to the late Dr. R. C. Knight. As a master of lucid expression he was also persuaded to undertake the editorship of the Station's Annual Report from 1935-45. Outside E.M.R.S. his eminence in mycology and plant pathology was recognized when in 1940 he occupied with distinction the Presidential Chair of the British Mycological Society, and from 1931-45 he was Joint Editor of the Transactions of that Society. He was also a Council member of the Association of Applied Biologists from 1937-39, and a vice-president 1938-39.

Even with such a full professional life Wormald found time to indulge other hobbies than his walking and beloved field-botany, principally the music of the pianoforte (particularly the sonatas of Beethoven), ball-games, and photography. Thus he and Jesse Amos were the first Station photographers, and as a founder member of our cricket team he was rightly feared for his subtle delivery of ' leg-spinners '. He was also greatly in demand at Station functions as a pianist. These activities alone would surely have sufficed for most people, but Wormald was also a natural linguist, and as his

research code insisted on a mastery of the world literature of any problem he tackled, he quietly set himself from the outset of his career to acquire for reading purposes German and the other languages of his science. At the time of his retirement he could translate readily into English botanical papers in no less than seven languages, including Russian.

In 1939, at age 60, Wormald relinquished his two principal offices at East Malling, but remained until 1945 to continue his researches, particularly at that time his pioneer studies of the Bacterial Canker diseases of the stone fruits, to edit the Annual Report, and to continue to give us the benefits of his ripe experience. Then, in the latter year he joined the staff of the Commonwealth Bureau of Horticulture and Plantation crops, at Bradbourne House, where for no less than seven years he worked daily, almost entirely on abstracting not only world phytopathological literature, but also scientific papers in every other branch of horticultural research appearing in the languages which he had mastered. It was at this time that he also started collecting material for new editions of his two principal works, the monograph on the ' Brown Rot Diseases of Fruit Trees ', first published in 1935 as Bulletin 88 of the Ministry of Agriculture and Fisheries, and his book ' Diseases of Fruits and Hops ', the standard work of reference on this subject, first published in 1939 by Crosby Lockwood and Son Ltd. Until 1949, when he began to be troubled by the illness to which eventually he succumbed, he continued his customary five mile daily walks to work through orchards and hop gardens, notwithstanding that the transfer to Bradbourne had lengthened them by a mile. In 1952, at age 73, he finally retired, a sick man, from his post in the Bureau, but only to face with characteristic determination the arduous completion of the new editions of his two *magna opera*. Quite literally he determined to finish these before he died, and in the opinion of his doctors his expectation of life was in fact exceeded by some years. So, slowly, with intermittent breaks when he had to take to his bed for a while, supported by the unflagging and devoted help of his wife, and with whatever technical aid we were able to supply from East Malling, complete these two immense tasks he surely did, and in 1954 the entirely re-written Brown Rot monograph was published by the Ministry (Technical Bulletin No. 3) ; and in June, 1955 he saw the new edition of his textbook in print. Soon afterwards he took permanently to his bed and died within six months.

Our abiding impressions of Wormald as a research chief and mentor are first and foremost the self-effacing humility and integrity of his approach to any research problem he tackled, and then his absolutely single-minded devotion to its solution. He always insisted on realizing each problem, in all phases of his work on it, within the context of its complete world literature, and in establishing friendly and creative relations with his fellow workers in whatever country. Then, mastering the literature and establishing appropriate liaisons, he would minutely pursue his experimental investigations in quiet and unhurried fashion, but with unremitting patience, tenacity, and singleness of purpose, until the primary etiology of the disease under investigation had been completely elucidated. It was only then that he would relax his attention in favour of the next problem, when he was content to hand over to others the ultimate applications of his findings in terms of practical nursery and orchard control measures.

As a man, in his dealings with his colleagues, students and other associates, he is remembered for his invariable kindness and patience, and his willingness immediately to put his unrivalled mycological lore and experience at the disposal of anyone who sought his counsel, were he the youngest and most over-confident of students ; and he never complained when he was thus disturbed. In his personal judgments he patiently sought out, and dwelt on, the good qualities of his students, colleagues, and associates ; but in the research criticism he tendered he was always inexorably objective and direct. His name will live in his published works as long as the pathology of horticultural crops is practised, but for a long time to come his good counsel, and always kind, smiling, and quietening companionship, will be greatly missed by those of us who were privileged to know and work with him.

R. V. Harris

Part I

THE EXPERIMENTAL FARM

By F. H. VILLIERS, with contributions from M. M. MACNEILL and H. R. BYFORD

Although some parts of the country suffered severely from drought, and other parts of Kent from storm damage, 1955 was a very favourable year for fruit growing here at East Malling. After prolonged snow and frost in the early part of the year, there followed a cool, though mainly sunny, spring and early summer. The spring was a late one. From July onwards the summer and autumn were warm and sunny. Apart from May the spring and summer months were generally dry, which greatly facilitated all outdoor work. There were fairly extensive spring frosts but damage was not as bad as was at first thought and Bramley's Seedling and Lane's Prince Albert were the only varieties which suffered appreciably, though the set of Cox's Orange Pippin, which was poor, may have been reduced to some extent. Drought conditions during the summer, which were disastrous in some places, were broken here by several heavy storms, which, though they did great damage elsewhere, brought only very welcome rain to East Malling. These storms undoubtedly did much to maintain reserves of soil moisture and give fruit size, which was very satisfactory, especially as regards apples and pears. One brief hailstorm disfigured part of the crop of some of the softer varieties of apples ; only the western sides of the more exposed fruits were affected and little financial loss resulted.

The season started exceptionally late ; cherries were not in full bloom until 1st May and the first Royal Sovereign strawberries were not picked until 22nd June, a full week later than in 1954. Things became more normal, however, as the season progressed and in fact some of the later varieties of apples, such as Barnack Beauty and Jonathan, were picked a few days earlier than usual.

Experimental orchards

Top fruits

Apples.—1955 was for several reasons a year of light crops for some of our main varieties of apples, but the increasing production of younger plantings and heavy crops of other varieties combined to produce a total of 11,908 bushels (40 lb. to a bushel) of excellent quality fruit. The blossom on both the plantations of Bramley's Seedling was damaged by frost on the night of 25th April ; this was probably partly responsible for the low crop of 1,032 bushels, about half the average of recent years. The crop was much poorer on the rootstock trials on Great East field, where the average yield was only 2½ bushels per tree, than on the plantation in Kiln Field where slightly smaller trees averaged 7 bushels. As these plantations are similarly situated only a few hundred yards apart, this is difficult to explain. There was much less blossom on Lane's Prince Albert than there has been for some years and some of this too was damaged by frost. The crop in consequence was a poor one, only 550 bushels as compared with 1,382 from the same number of trees in 1954.

While trees of Cox's Orange Pippin on M.IX cropped even better than usual, larger trees of the same variety on M.XII in the manurial trial on Churchfields East and on various rootstocks, some of them seedlings, on Kiln Field cropped poorly. On the newer plantations on Churchfields West and at Larkfield there was rather more blossom on Cox than on the older trees just mentioned, but even here the crop was by no means heavy. In contrast, our other main dessert variety, Worcester Pearmain, cropped heavily and a total of 4,687 bushels, was harvested, the most ever produced on the Station. Blossom was not unduly heavy but the trusses were evenly spaced with the result that little labour had to be expended on thinning the fruit, and an excellent crop of good-sized fruit was harvested. The best crops came from the larger trees on Great East Field, now 35 years old ; the younger trees on the new plantations, though they made a useful contribution to the total, were somewhat disappointing.

Considerably more than half the trees of Ellison's Orange and Laxton's Superb were in an ' off ' year and crops were in consequence less than in 1954. Those trees which blossomed fruited heavily and the fruit was of good size and quality. Trees of Ellison's Orange on the younger plantations were all ' picked over ', but the older frameworked trees on Kiln Field were sprayed to prevent pre-harvest drop. These measures, combined with the abundance of sunshine, resulted in much improved

fruit colour on this variety. The Laxton's Fortune on M.II and Sunset on M.IV on Churchfields West have not given a very impressive performance since they were planted in 1945, and crops have been much less than from comparable trees of Worcester Pearmain and Ellison's Orange. Growth has been excellent and the trees appear healthy, but crops have been small and, possibly because of the dense foliage, the fruit has been poorly coloured. At the time of planting, little was known here about the requirements of these two varieties, the trees of which have been closely spur pruned ; lighter pruning might have given better results. On the other hand Jonathan, the trees of which are regulated, has done well. The fruit has been a little on the small side and the trees are inclined to be susceptible to Mildew, but so far they have cropped regularly and well, and the colour has been good.

Pears.—1955 was by far the best ' pear year ' at the Research Station for some time, though we have now only a small cropping acreage ; the total crop marketed was 827 bushels (48 lb. to a bushel) against 616 in 1954. After a light crop of 1 bushel per tree in the previous season the trees of Dr. Jules in the mixed plantation on Churchfields East, after being fruit thinned, bore a splendid crop of good quality fruit as did the Williams' Bon Chrétien and Conference in the inarching trial on Egham Field. The other plantations cropped fairly satisfactorily, including the 34-year-old trees of Conference on quince rootstocks in Egham Field, which yielded an average of 97 lb. per tree, the most since 1952. In spite of the favourable season and the excellent soil there, much of the fruit of Williams' in the trial of clonal pear rootstocks on Deadman Field was small. There was some bird damage to buds on this plantation and also to the pears in Bradbourne Gardens, but the main pear plots were not seriously affected.

Cherries.—The 6½ acre plantation of Early Rivers, Bigarreau de Schrecken, and Turkey Heart again did well ; there was plenty of blossom and this did not appear to be damaged in any way by frost. The weather at picking time was much less showery than in 1954 and there was much less fruit splitting. A total of 1,091 halves (24 lb. to a half sieve) was marketed, compared with 856 in the previous season. The two cherry plantations planted in the autumn of 1953 made excellent growth and Bacterial Canker has, so far, been successfully kept at bay.

Plums.—Except for the variety Victoria, 1955 was a poor year for plums at East Malling. Generally blossom was light and this may have been accentuated by bird damage to fruit buds. On the gage plum variety and rootstock trials, the trees in which are about 15 years old, many varieties bore little blossom and scarcely any fruit. Even the Warwickshire Droopers, which have cropped very regularly since they first came into bearing in 1946, failed and only 62 halves (28 lb. to a half sieve) were marketed from 44 trees. The only variety in this plantation to do well was Ontario, 88 trees of which averaged just over 100 lb. per tree.

The young plum plantation on P.9, planted in 1948, cropped much more heavily for the size of tree, Victoria averaging 90 lb., Marjorie's Seedling 30 lb., Cambridge Gage 25 lb., and Early Laxton 10 lb. per tree.

There was some bird damage to fruit buds on both these plantations, trees of Early Laxton and Cambridge Gage suffering severely, whereas Victorias were hardly damaged at all.

Soft fruits

The total crop of raspberries, almost 7 tons from just over 2 acres, was ¾ ton more than that of the previous year from the same acreage. Towards the end of the picking season many of the fruitlets shrivelled through lack of rain, but, even so, the crop was very satisfactory, considering that all plantations have now carried 8 crops.

There were approximately 3 acres of fruiting strawberries in 1955, including ¼ acre fruiting as maidens and ½ acre in pathology trials from which little fruit was picked. The total crop from all plots was 6 tons 6¾ cwt., though not all of this was of dessert quality. Most of the beds were sprayed twice with captan and *Botrytis* was not nearly so troublesome as in 1954, but Mildew attacks were severe and only partly kept in check by frequent light dustings with sulphur. The early varieties Madame Lefebvre and Royal Sovereign suffered most from Mildew but all were affected. Though the plants were very variable the ¾ acre of Climax in Deadman Field bore a useful first crop and it is thought well worth while to crop them again next year. Plants from healthy parents showed little sign of ' yellows ' but those from unhealthy parents were very stunted and it was possible to tell almost to a plant which bundles of runners were healthy at planting time. A variety of measures were tried in order to lessen damage by ground beetles; some appeared promising, but it is too early yet to make any recommendations.

Fruit marketing

Lighter apple crops this year gave good fruit size without the need for much thinning, and the warm sunny weather at picking time helped to colour the fruits of all varieties. The bulk of the apple crop was size-graded and marketed in 40 lb. non-returnable standard apple boxes marked to

show the number of apples they contained. Our salesmen are unanimous that the 40 lb. standard box is a most satisfactory type of package and the extra cost of marketing the fruit in this way was probably well repaid in improved prices. Accurate size-grading is essential for this type of pack and in this respect the new size grader recently installed was of the greatest value, far superior to the old weight grader it replaced. Both Fancy and Choice grades were wrapped and packed in standard boxes and sold readily. The proportion of Fancy grade fruit, though higher than in 1954, was not as high as might have been expected in such a favourable season. Too many fruits had to be down graded because of excessive russeting.

In last year's Report the construction of four new 800-bushel apple stores was mentioned. During the past summer these have been fitted with scrubbing apparatus so that the percentage of both oxygen and carbon dioxide can be controlled ; this will greatly assist research in progress on field factors affecting the storage life of Cox. Two of the stores are being used for this purpose—one as an ordinary cold store, and the other as a gas store with 3 per cent oxygen and 5 per cent carbon dioxide. Of the other two one has been filled with Laxton's Superb and Jonathan and is being maintained at 5 per cent oxygen and 5 per cent carbon dioxide, the other is being used as a cold store for Jonathan and Barnack Beauty. It is hoped by this means to compare the keeping qualities of Jonathan under the two methods of storage and also to find out the most profitable time to market them. Of the three older stores one was filled with Worcester Pearmain from picking time till mid-November, the second with Cox for storage till Christmas, and the third with Bramley's Seedling and Lane's Prince Albert for keeping until the new year.

Most plums and gages, including Victorias, were sorted over a moving belt and marketed in 12 lb. chips. Quality was on the whole good, except for the Victorias from the young trees on Park Farm ; these cropped more heavily than expected, and, not having been thinned, produced a good deal of small fruit.

Some strawberries were marketed in 1 lb. punnets but the bulk of the fruit and all raspberries were sold for processing, as sufficient labour could not be found for picking and the preparation of dessert fruit for London markets.

Fresh plantings and grubbings

Now that the post-war apple, pear, and plum plantings are coming into cropping, more of the older plantations which have ceased to be of much experimental value have been grubbed. The mixed apple and pear plantation on Churchfields (C3) is being grubbed this winter and will release $4\frac{1}{4}$ acres of good fruit land for use for further trials in due course. For the same reason it is proposed to grub the four most easterly rows of Worcester Pearmain on Kiln Field (K7). On Great East Field a further two rows of the old cordon apple and pear collection (G8), the small plot of dwarf pyramid pears (G17), and the most easterly row of apples on M.IX (G18) are to be cleared. On Upper Grub the one-acre raspberry mulching trial has come to the end of its experimental life and is to be grubbed ; a new trial is being planted on Egham Field (E35). The bush peaches in Bradbourne gardens, the gage plum rootstock trial (D2), and the Conference pears in the quince rootstock trial on Egham field (E36) are all to be thinned owing to overcrowding.

The Station has now reached the stage when all suitable land has already been used for fruit experiments of some sort. Measures to bring such land back as soon as possible to a state of uniformity and fertility in which it can again be used are constantly being sought. Meanwhile, an adequate period, during which only uniform arable crops are grown, is insisted on.

Apart from experiments that start at planting time, mature trees, bushes, and other fruit plants are in constant demand by all Sections. To meet this demand, plantations have in the past been planted up on which no experiments have been started until the trees or other plants were established. In continuation of this, $1\frac{1}{2}$ acres of Norfolk Giant and Malling Exploit raspberries on Newgates Field, will be planted early in 1956. This will be followed with 2 acres of black currants and about 5 acres of pears that are now in the nursery, and later with a plantation of plums. Apart from their research usefulness, these will help to redress the balance of fruit plantings on the Station which at present consist largely of apples.

In addition to these, the following specific experiments are being planted on Egham Field this winter :—

Half an acre of Norfolk Giant, Malling Exploit, and Malling Jewel raspberries for an irrigation and mulching trial ; one and a half acres of Napoleon cherries, at 18 ft. square, for a trial to test different spray programmes for the control of Bacterial Canker ; and a small trial of some 80 dwarf pyramid Cox trees, with Worcester pollinators, to test the regularity of bearing of certain strains of Cox's Orange Pippin.

In addition to the more or less permanent trials there is, each year, a lot of planting to do for small scale and laboratory trials. In the spring of 1956 there are to be planted just over a thousand

trees for breeding investigations, a similar number in connexion with virus work, ½ acre of fruiting strawberries, and three small runner beds, two small trials for the Physiology Section, two for the Pomology Section, and two for Plant Protective Chemistry.

Routine spray programme 1954-55

Continuing last year's policy of reducing winter washing to a minimum, none of the older plantations of apples, pears, or cherries received any tar oil or DNC during the winter of 1954–55. Cherries had been sprayed with 8 per cent tar oil in December, 1953 to prevent the build-up of Cherry Fruit Moth, but it did not seem necessary to repeat this. All plums, peaches, and soft fruits were sprayed with 5 per cent tar oil during December, and also certain small scale and laboratory trials as a precautionary measure.

A single spray of DDT emulsion applied to apples between the mouse-ear and green-cluster stage of bud development did not prove sufficient to check a severe infestation of Oat-Apple Aphid which developed on many varieties of apple, especially Worcester Pearmain and Bramley's Seedling. These aphids did not migrate to their alternate hosts as quickly as was anticipated and a good deal of leaf puckering resulted.

The scab-control programme for apples and pears again closely followed the recommendation of the spray calendar, except that all dessert apples received one application of captan, 50 per cent wettable powder, at the rate of 2 lb. per 100 gallons, immediately before blossoming, and all pears the same treatment for both post-blossom sprays. No damage resulted from the use of this material on any of the varieties grown at the Research Station. Fruit Tree Red Spider Mite had been so reduced by last season's two applications of ovotran that a single spraying this year seemed likely to be adequate and, indeed, in mid-June this looked like being so. The prolonged spell of warm sunny weather, however, proved so favourable for the mite that there was much bronzing of leaves late in the season, though too late to have much effect on the fruit. BHC, 50 per cent wettable powder, at 1 lb. per 100 gallons, at 80 per cent petal-fall was used to control Apple Sawfly, and all plantations received two lead sprays against Codling Moth, one at the end of June and another 2 weeks later ; both treatments were effective.

Both cherries and plums received exactly the same spring and summer sprays as were outlined in last year's Report, but all young cherries had an additional Bordeaux mixture spray at 4 : 6 : 100 at petal-fall as an extra precaution against Bacterial Canker. Raspberries were again only sprayed twice during the summer, once with BHC against Cane Midge in May and once with derris at the pink fruit stage against Raspberry Beetle. This pest seemed particularly prevalent in 1955 and it might have paid to give two sprayings or dustings.

Fruiting strawberries were sprayed twice with malathon to control aphids in preference to the parathion previously used, as it is much less likely to be toxic to humans. Two sprayings, one at the end of April and one after fruiting, appeared to give good control. A mixed dust of sulphur and 5 per cent DDT was applied in early May at 56 lb. per acre against Mildew and Strawberry Rhynchites. As Mildew was so prevalent the sulphur dusting had to be repeated several times up to, during, and after fruiting. Fruiting beds were also sprayed twice with captan at the rate of 2 lb. of 50 per cent wettable powder per 100 gallons against *Botrytis*, the first application being made at early petal-fall and the second 10 days later. Efforts to combat ground beetles included the placing of poison baits and spraying the headlands with dieldrin.

Arable Crops

Altogether some 129 acres of the Experimental Farm were occupied by arable crops during 1955. This land includes areas recently cleared of old fruit experiments and being given a four-year rotation of arable crops in preparation for future fruit and nursery plantings ; land which is too liable to frost to be satisfactory for fruit ; and land which is too variable for experimental purposes owing to outcrops of rock, old ponds, carriageways, etc. Though the total area of arable crops remains fairly constant, it is largely made up each year of scattered pieces of ground, most of which are under 5 acres. Ground which has been under fruit is frequently infested with couch and other weeds from around the old tree bases, full of roots, and on the acid side, for ordinary arable crops. In spite of these difficulties, however, the arable crops usually make a useful contribution to the farm revenue and did particularly well in 1955, when the average gross return per acre of cash crops grown was £68. The land was cropped as follows :—

Potatoes.—The potato area this year was made up of 6 acres of Ulster Premier—a King Edward type early ; 5 acres of Craig's Royal—a partly coloured second early ; 5 acres of Dr. Mackintosh ; and 1 acre of Majestic. The earlies were grown on the site of an old cherry orchard to assist in getting rid of a legacy of couch ; they were lifted in late June and yielded just under 4 tons per acre. The

land was then fallowed for the rest of the season and most of the couch destroyed. The Craig's Royal were dug in August and 72 tons of potatoes were sold from the 5 tons of seed planted. The Dr. Mackintosh and Majestic were lifted in October and averaged 14 tons per acre.

Peas.—Three varieties of peas were again grown in 1955 :—7 acres of Thomas Laxton for quick freezing, and 5 of Surprise and 4½ of Lincoln for canning. All varieties were sprayed with DNBP for weed control with excellent results. The peas quickly recovered from the slight check and almost all weeds were eliminated, little hoeing being consequently necessary and harvesting greatly facilitated. The Thomas Laxton, cut at an early stage for quick freezing, yielded 30 cwt. per acre, the Surprise 40 cwt., and the Lincoln 50 cwt. per acre.

Cereals.—Twenty-two acres of wheat, 18½ acres of barley, and 8 acres of oats were grown ; all did fairly well. The oats, Blenda, threshed 10½ qrs. per acre ; the barley, all Plumage Archer this year, 6 qrs. per acre ; and the wheat, largely Atlé, also 6 qrs. Most of the wheat was sprayed with DNOC to kill mayweed and cleavers which threatened to become a nuisance, and results were again excellent. A large part of the barley, which was undersown with clover and ryegrass, was sprayed with MCPB ; there was no damage whatever to the clover and the weeds were to some extent reduced.

The S.37 Cocksfoot which is being grown for seed in Ditton Fields also yielded well, giving just over 600 lb. of ' head ' seed per acre and about 30 cwt. of straw. Seven acres of roots and kale were also grown for feeding to the two yards of Devon steers which are wintered every year to tread our straw into dung. F.H.V.

Experimental nurseries

The lifting season commenced on 8th November with the soft fruit bushes ; these and the cuttings of Amos Black black currants were dispatched before harvesting began in the stoolbeds on 17th November. A total of 95,445 layers—from 23 apple, 2 quince, and 4 plum and cherry types of root-stock—were harvested and dispatched during the winter, the bulk having been sent away by February.

The rootstocks rooted well on the stools, but the growth was a little slender. The large majority came in the 5/6 mm. grade but were well-rooted.

There was a heavy demand for rootstocks and other material to be sent overseas, a total of sixty-one consignments being sent to 20 different countries, including Germany, France, Australia, India, and the American continent.

A break in the work of dispatching caused by the proximity of the Christmas Holiday enabled the staff to turn their attention to lining out the 1955 budding nursery. This occupies some four acres and contains approximately 20,000 stocks of twenty-five different types, nearly all of which were budded during the summer to produce trees for experimental purposes.

The summer of 1955 will be long remembered as an exceptional year. Drought conditions prevailed for the greater part of the growing season, and when it came near to the time for lifting, it was questionable whether the operation could be carried out successfully with the soil in such a hard, dry state. However, a timely thunder storm broke the long drought and made conditions appreciably easier. Happily the dry weather does not seem to have had any deleterious effect on the maiden growth. The drifts of stocks which were budded in 1954 managed to find sufficient moisture and the bud growth continued through the summer until we approached the winter with a fine stand of maiden trees of good height and vigour.

Last year Apple Mildew was so bad in the stoolbeds that the crop was in some cases considerably reduced. This year a determined effort has been made to control it. A watch was kept for the first signs of the disease and then the whole nursery area was sprayed with lime-sulphur. In all nine such sprays were given and, although a few traces of the disease appeared very late in the season, in the main it was completely controlled. A tractor-mounted boom sprayer was used and proved as effective as a hand lance. The saving in time and wash was considerable and the whole operation was far less costly than might have been expected. One tractor driver alone, mixing his own wash, can spray an eight acre stoolbed in a day, using a fraction of the spray material needed to do the same area with hand lances. Apart from this there was the great saving of not having any diseased and therefore useless shoots on the stoolbeds.

The economy and effectiveness of this method of spraying has been so marked that the 1956 budding nursery is being planned in blocks with a spray alley every sixth row, so that the lined-out stocks (and the bud-growths until they grow too tall) can be sprayed automatically.

The range of varieties to be issued as virus-tested mother trees has been extended, and eight varieties of apples and twelve varieties of cherries budded during the summer will be available in the autumn of 1956. The virus-tested mother trees budded in 1954 and available to Members this year are in good demand.

During the late winter of 1954–55, three acres of new stoolbeds were planted with virus-tested clones of nearly all the Malling-Merton varieties. Each section of the stoolbed is being carefully extended with the progeny of one selected and tested individual, and, when the stoolbed is in full production, it is hoped to be able to supply all research requirements with material that is fully tested and free from known viruses.

Experimental glasshouses

The ' glasshouse area ' now extends over two acres and includes twenty-one houses of many different types and sizes, numerous frames, the potting shed, various shelters, special equipment for mist culture experiments and sand culture investigations, as well as the essential plunging ground, all of which are maintained by the greenhouse staff.

One Dutch light house, 40 ft. by 13 ft., with alternate side panels gauzed, has been erected for raspberry breeding, and some modifications have been made on existing houses. One of the former ' Festival ' houses has been adapted so that half of it can be used as a laboratory, the glass roof being replaced by an insulated roof covered with sheet aluminium, and the other half equipped with scrim blinds on the roof sides and end.

The Dutch light house built during 1954, mainly for winter use, was extended by 10 ft. during the present year. This house is now fitted with thermostatically controlled heating and has a number of light units controlled by time switches. Three benches have been provided for small plants, such as apple seedlings and hop cuttings, and there is space for fair-sized trees in the centre of the house.

During the spring all the remaining wood lath blinds and supports were fitted to the roof of both virus houses. This made it possible, with hardly an exception, to keep temperatures inside the house below 90° F. during a summer which has been notable for its sunshine. This is a great improvement, when it is remembered that temperatures in the region of 100° F. and above were quite common during 1951.

A tubular metal and wire netting bird-proof shelter was erected adjacent to the timber shelter early in the year and, in the spring, another bird-proof shelter, 80 ft. by 20 ft., was erected using angle iron for the frame. This latter shelter has a sloping roof so that tall upright cordon trees can be accommodated as well as bush trees. The roof is 12 ft. high at the north and 8 ft. at the south side, and has hessian screens which can be used to cover it during cold nights or very sunny days immediately after the trees have been removed from the glasshouse where they have been forced.

Small numbers of apple seedlings have been raised from September to May by first subjecting the seeds to controlled periods of cold, and then germinating them in a heated glass house with supplementary light.

The growing season of some cordon apple and pear trees has been extended with the aid of artificial heat and light. Similarly, by suitable cold treatment during November and December, trees have been forced into growth early in January.

The use of lime in the potting compost has been varied to ascertain the effect, if any, on the growth and health of seedlings of various fruits. Apple seedlings appear to do much better with lime in the compost, whereas some stone fruit seedlings have a better leaf colour if lime is omitted. It should be remembered that the water used for watering is fairly hard and this probably helps to maintain the calcium content of the compost.

With some seedlings, especially *Rubus* species, root development has been quicker when a larger proportion of sand than is usual has been added to compost.

During the last five or six years there has been a steady increase in the numbers of seedlings and plants raised and maintained under glass, last year the numbers of seedlings alone being in the region of 18,000. M.M.M.

Part II

GENERAL REVIEW OF RESEARCH WORK
WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

I. POMOLOGY

By W. S. ROGERS

Crops of tree fruits were rather variable, but those of small fruits were good. This was probably due to the cold, late spring and the warm sunny summer. Bird damage to buds seriously affected the yields of plums, gooseberries and certain pears. Such damage appears to be becoming more serious, both from the experimental and the commercial points of view.

Two papers were presented to the 14th International Horticultural Congress, in Holland. Some seventeen papers published during the year are listed on pages 29 and 30.

Tree fruits

The field trials, covering some 78 acres have been maintained. As usual only the main changes and points of interest will be reported.

Rootstocks

In this, the first year of general release of trees on five new rootstocks, it is good to be able to record that trees on all these rootstocks have continued to do well in our trials. Malling-Merton 104 has produced trees which have cropped more heavily than any others in their first eleven years ; on our loam soil, trees on MM.111, almost identical in size with those on M.II, have excelled them in yield ; and trees on M.XXV have yielded better than those on M.XVI, which are similar in size. On poor sandy soil, trees on MM.106 have proved more suitable for filler trees than those on M.IX ; and trees on MM.109 have grown better than those on M.II, which suffered severely from drought.

Trees on the new ' M.IX Cross ' rootstocks again bore well, the variety Egremont Russet being outstanding for its regular cropping and good quality. A small trial has been planted to compare two slow cropping varieties, Blenheim Orange and Northern Spy, on the new very vigorous rootstock M.XXV and on M.XVI.

A research paper on Malling-Merton rootstocks was published (E.412) and also two popular accounts, one of which was published in Australia (E.435 and E.391). Detailed botanical descriptions of the whole series of Malling apple rootstocks were published (E.423).

Routine records have been maintained in the pear rootstock trials.

In the 9-year-old trial of semi-dwarfing plum rootstocks, Victoria has done well on all rootstocks except Ackermann's. On Common Plum it gave crops of 120 lb. per tree. Other varieties yielded less, Cambridge Gage on Marianna giving nearly 40 lb. per tree, and Marjorie's Seedling on Marianna 45 lb. per tree.

In a new semi-dwarfing plum rootstock trial, now 4 years old, some differences in vigour are already apparent.

Nursery and preliminary field trials of species of cherry other than *P. avium*, as rootstocks for sweet cherries, continue to indicate the unsatisfactory nature of many such combinations.

Incompatibility

The union structure of some double-grafted, and some single and double-shield budded trees of Williams' Bon Chrétien pear on quince rootstocks, has been examined. Structural abnormalities usually associated with incompatibility were observed in the phloem of all pear/quince unions, including those of combinations capable of making a satisfactory tree in the field. The extent of the abnormality was, however, related to the degree of compatibility. A study was made of the origin and spread of necrosis in the phloem of incompatible combinations and a paper has been prepared on this subject.

A field trial, now seven years old, of various compatible and incompatible plums, is now beginning

to show some breakage at the union. The trial shows that Reeve's Seedling is incompatible not only with the rootstock Myrobalan B, but also with the plum varieties Victoria, President and Oullins Golden Gage. This confirms observations made on one- and two-year-old unions.

The structural changes associated with the presence of a graft union, as distinct from those due to incompatibility between varieties, have been studied in unions of single-worked trees of the plum rootstocks Brompton, Common Plum, and Myrobalan B grafted together in all combinations. The unions were examined both macroscopically and in radial longitudinal section.

Preliminary compatibility tests of potential new rootstocks for stone fruits are being made. Plants of each new clone were budded with a plum variety, a greengage, and a peach.

Many of the pears budded on a wide range of *apple* rootstocks in 1953 have died but there was considerable variation in degree of incompatibility ; a note is in preparation.

A paper was published (E.426) on symptoms of incompatibility induced in a peach by ring grafting with an incompatible rootstock variety.

Histology

Groups of apple seedlings, from families that had already undergone biological tests for resistance to the Woolly Aphid, were selected for further work on the relationship between this resistance and the histology of tissues near the periphery of young stems. The families were raised from Northern Spy crossed with the scion varieties Ben Davis and Laxton's Superb, and with the rootstocks M.I. Studies of the developmental anatomy of the phelloderm and collenchyma in shoots of resistant and susceptible varieties were continued.

The origin and anatomical structure of naturally occurring and artificially induced sphaeroblasts in apple and some other species has been studied, and a paper on this subject is in the press. Arising from this work an investigation has been begun of differences in the histology of juvenile and mature stems.

Work has been continued on the relationship between the numbers and the distribution of primary phloem fibres in young stems and the ability of the stems to produce adventitious roots.

An examination has been made of the tap root structure of seedlings from species belonging to the genus *Malus*, and to the sub-genera *Prunophora*, *Cerasus*, and *Amygdalus*. In particular the relative amounts of bark and wood present in the tap root were recorded. Certain seedlings were selected on their root anatomy for further trial. The structure of lateral roots from five-year-old plants of *P. armeniaca* was recorded and compared with that of the tap root of the same seedlings at six months old.

Work is being continued on the periods and relative rates of production of phloem and xylem in roots from M.IX, M.II and Crab C. Unworked plants of these rootstocks have been found to differ in the relative proportions of root, stem and leaf as well as in root anatomy. The relationship between the morphology and anatomy is being studied. Treatments applied to the above ground portion of the tree have been shown to affect root structure. Summer pruning increased the amount of bark in roots, while exceptionally severe winter pruning (stooling) reduced it. Defoliation tended to reduce the amount of bark in roots. The roots of young trees that were deblossomed had less bark than those that were allowed to bear fruit. Roots from mature trees bearing heavy crops had a greater proportion of bark than those from similar trees bearing light crops.

Although, in general, the proportion of bark to wood in roots has been found to decrease with increasing root size, it has also been shown that young roots that have made rapid growth have a smaller proportion of bark than older roots, of the same diameter, that have grown more slowly.

Scion influence on root structure has been measured in composite apple trees. Roots of trees bearing vigorous scions have been found to have a lower bark/wood ratio, and a smaller proportion of ray tissue in the wood, than roots from trees of the same clone grafted with dwarf scions.

The anatomy of stems and roots of plants infected with certain virus diseases has been compared with that of healthy plants.

Propagation

A number of ' easy rooting ' apple varieties have been collected for observation. A batch of *Pyrus callervana* seedlings is being examined for growth habit ; selections will be tested for rooting capacity and for compatibility with pear varieties. Four selections of Pershore plum from Worcestershire have been layered to evaluate their propagation qualities.

Studies have continued jointly with the Physiology Section. Published papers included reports on the influence of source and of growth substance on apple and plum cuttings (E.418), on production of sphaeroblast shoots of apple (E.425), on experiments with apple, pear and cherry root cuttings (E.424), and on cherry tree production (E.419). A paper on the interplay of factors influencing rooting behaviour of cuttings was presented to the 14th International Horticultural Congress, at The Hague. A report on source of black currant cuttings has been prepared (see page 61).

Double-working

The ten-year trial of double-worked Williams' bon Chrétien pears on quince rootstocks at Throwley has been completed. Trees with intermediates of Beurré Hardy or Fertility were superior to those with Beurré d'Amanlis or Hessle.

The double-shield budding method of double-working, used with success with pears on quince is under test as a means for overcoming apricot/plum incompatibility in the nursery. The double-shield technique was described in a paper read at the International Horticultural Congress.

Soil management and manuring

In the classical manurial trial, on which a sward *v.* cultivation factor was superimposed in 1953, the trees in the sward plots still appeared rather nitrogen-deficient in 1955, though less so than in 1954, suggesting that the phase of initial competition by the swards is passing.

This initial phase has probably already been passed in the trials of Laxton's Superb and Laxton's Fortune on M.II under sward, mulch, and clean cultivation. It is now five years since the experimental treatments were started, and the trees are now 11 years old. Growth was uniformly good this year.

The straw mulch plots in several trials have become seriously infested with couch grass. The validity of earlier observations on the effects of mulches is not in question, for the infestation has only recently become appreciable. Work with weedkillers (see below) may perhaps suggest a useful means of control.

Apart from investigations on soil management in the orchard, consideration has been given in recent years to the possible influence of the past management of the soil. Following the report of 1953, in which tree performance was shown to be related to previous agricultural use of the land, a historical study of part of the Research Station land was made, in collaboration with the Statistics Section. The results, which were published (L2) in last year's Annual Report, suggested that certain areas are likely to be variable on account of their history.

Weedkillers

In addition to continuing the existing trial, investigations were started in an attempt to find a means of controlling couch-grass in the orchard, both locally round the base of the trunks and in straw mulch. Treatments include sodium chlorate, diesel oil alone and fortified with DNC, and 2:2-dichloropropionic acid (' Dalapon '), a chemical recently introduced for weed control in the U.S.A.

Soil studies

Studies of the effect of different methods of soil management upon the available soil moisture have continued. Large effects on percolation of rain, on evaporation and on retention of water have been found ; and these are helping to explain the effects of these cultural practices on tree growth and cropping.

Two papers have been prepared ; one on soil moisture deficits developed under uncut grass and grass mown frequently, and the other on soil moisture deficits developed under three grass species subjected to a uniform management of frequent mowing (see pages 64 and 69).

Restoration of soil uniformity

In the trial, carried out in collaboration with the Statistics Section, on the restoration of soil uniformity after grubbing an old orchard, the closely-spaced trees of Cox's Orange Pippin on M.VII rootstock have made their second year's growth from the bud. The growth will be fully recorded in the dormant season in order to provide information on the degree of soil uniformity achieved by the various treatments.

Root studies

Root studies have been continued on mature trees in the rootstock trials on different soils in Kent. Sectors of the root systems of trees on three different rootstocks have been excavated from two soil series overlying the Tunbridge Wells Sand of the High Weald. One was a very fine sand showing impeded drainage symptoms (Curtisden Series), and the other a loose textured brick earth (Ladham Series), the latter overlying the ' B ' horizon of an eroded profile of Tunbridge Wells Sand which limited depth of rooting. On the Curtisden Series there were symptoms of impeded drainage in the compact subsoil and rooting was reduced where these occurred.

These excavations complete the series of root studies on five soil types and the data are being prepared for publication.

Irrigation

Laxton's Superb apple trees receiving supplemental irrigation have again made more growth than the control trees receiving only rainfall. The absence of drought in recent years has restricted

the range of soil moisture conditions whose effects on fruit tree behaviour could be studied. In March, 12 ft. squares of polythene sheeting, raised from the soil to permit ventilation, were placed round two cropping trees of Laxton's Superb apple on M.II to deflect rainfall from the soil under the trees. The rainwater intercepted was run off to one side of the polythene. Comparison with two similar trees which received the season's rainfall showed drastic effects on total crop and on fruit size. The total weight of fruit picked from the trees in dry soil was 42 per cent of that from the control trees whilst the weight of crop in the size grades $2\frac{1}{4}$–3 in. was only 32 per cent of the controls. Heavy fruitlet drop early in the season, high fruit colour and early defoliation were also associated with the trees in dry soil. The soil was a loamy sand having a low reservoir of available water, and the dependence of trees on such soils on an adequate and well distributed rainfall over the growing season was well illustrated.

Pruning

The data from eleven-year-old pruning trials of Laxton's Superb apple, on two different soils, are being prepared for publication.

In the seven-year-old pruning and manuring trial of Victoria plum, differences due to pruning in the first three years are now much smaller, but an effect of nitrogen is becoming apparent. A tree shaping trial of Victoria plum on Myrobalan B has been severely affected with Bacterial Canker (*Pseudomonas mors-prunorum*). Losses have occurred both in the summer pruned dwarf pyramid trees, and in the half-standards which receive a little pruning in late spring. The unpruned trees have been least affected, the few cankers present occurring where the bark had been damaged by contact with a stake or during cultivation.

Trunk-cutting studies

Following on a suggestion made at the Amos Memorial Lecture 1954 a preliminary investigation was started on the effect of severely interrupting the conducting tissues of the stem, by cuts made with a saw on opposite sides of the stem, with special reference to the effects on bud dormancy.

The effects were studied of distance apart of the cuts and the timing of the operation, in relation to the stage of bud development, on cordon pear trees whose wirework provided a convenient support for the partly severed stems. Interesting results were obtained and the data are being summarized for reporting.

Fruit thinning

A research report on an apple thinning trial with the variety Duchess' Favourite was published (E.410) and also a popular account of thinning apples (E.420). A thinning trial with the apple Sunset, in collaboration with the Plant Physiology Section, has continued.

Biennial bearing

The studies of blossoming and cropping of various varieties and of relationships between fruit bud, fruit, and leaves are being continued.

In collaboration with the N.A.A.S. a trial to study the effect of defoliating sprays of copper sulphate at various concentrations upon fruit bud formation has been started.

Two trials of naphthalene acetamide as a possible fruit thinning agent have been carried out. Preliminary results show effects rather similar to those of naphthalene acetic acid. Unfortunately none of the blossom thinning materials used abroad have so far proved suitable for our climatic conditions, in our tests.

The use of various materials to remove all blossoms is being tested. This practice might be valuable either to change the phase of certain trees, or to remove unwanted fruitlets in early years. The materials tested included tar oil, DNC, and the anti-auxins ' endothal ' and tri-iodobenzoic acid. All these effectively removed the blossoms ; but the effects on subsequent growth and the economic aspects have yet to be studied.

Breeding

Rootstocks.—Breeding work for the production of improved rootstocks for cherries has been continued. *Prunus* species used in crosses with the East Malling selected Mazzards have included *canescens*, *pseudocerasus*, *pumila*, *spontanea*, *tomentosa*, *Japonica Nackai* and *Wadai*, with the object of producing rootstocks having a dwarfing influence on cherry scions worked upon them. About 200 seeds will be germinated in the spring.

In the search for new varieties of rootstocks combining compatibility with all varieties of pear scion with good nursery performance, further crosses with the pear/quince hybrid, *Pyronia Veitchii luxemburgiana*, have been made. Several fruits have been set by fertilizing flowers of this hybrid with apple pollen. A number of pear/apple hybrids, raised in 1954 are being carried on, but attempts

to repeat this hybrid in 1955, using different varieties, were not successful. It has not been found possible, so far, to double the chromosome number of *Pyronia* by the use of colchicine.

Scion Varieties.—About nine thousand seedlings, raised from crosses between Cox's Orange Pippin and several very late flowering apple varieties from the Continent, were established in the field during the year and several more crosses, likely to yield a further ten or twelve thousand seedlings, were made. From some six thousand seedlings planted out in nursery rows on their own roots in 1954, about six hundred relatively late in season of leaf break have been selected. These have been kept for observations on their time of flowering and other characters and the rest have been discarded.

Work in collaboration with the Entomology Section on the breeding and selection of apple scion varieties of good fruit quality highly resistant to attack by Woolly Aphid has been continued and a number of seedlings from crosses made last year between Northern Spy, Cox's Orange and Crawley Beauty are now undergoing test. Further crosses between Northern Spy, Court Pendu Plat, and Irish Peach were made this year.

Further selection has been made among earlier families of seedling apples and pears raised for the production of new varieties of high quality and extended season. Six apples with very early maturing fruits and seven pears which appear to combine good fruit quality with heavy and regular cropping have been retained for further trial.

Varieties and classification

In the gage and plum variety trial, now 18 years old, Ontario gave 100 lb. per tree, Victoria 65 lb. per tree, Comte d'Althann's Gage 60 lb., and Warwickshire Drooper 50 lb. per tree. Many plums suffered greatly from bird damage to buds and gave only light to medium crops.

In the trial of bush peaches, now seven years old, useful crops of good-sized fruit were produced by the varieties Hale's Early and Peregrine (32 and 17 lbs. per tree respectively) in spite of much dieback of the shoots. The yields of Bellegarde and Barrington were very poor, however. Bellegarde suffered badly from Bacterial Canker. The ten-year-old fan-trained trees on the walls yielded well, Peregrine producing 37 lb. and Sea Eagle 55 lb. per tree.

The variety collections of apples, pears and plums were maintained.

Small fruits

Variety and strain trials

Strawberries.—In two replicated cropping trials, new clones of Huxley, Perle de Prague and Early Cambridge, all freed from virus by heat treatment by the Pathology Section, were compared with older virus-tested clones, containing relatively mild viruses. The virus-free Early Cambridge, and to a lesser extent Huxley, clones were more vigorous and cropped more heavily than the old ones. To clarify our terms it is worth noting that ' virus-free ' means (and can only mean) free of all known viruses, according to the best current methods of testing for infection. A virus-tested clone is one that has undergone approved tests and if not virus-free is at least of known virus status. Where a virus-free clone is not available, a virus-tested clone containing only mild viruses can prove very valuable—as was the case with Huxley M.44 ; but it is obviously desirable, from the health point of view, to replace such clones with virus-free ones whenever possible.

Small preliminary trials of four other heat treated clones, Mme. Lefebvre and Cambridge Prize-winner, Rearguard, and Favourite produced their first crops. A small preliminary trial of Talisman also cropped as maidens.

Plants of different stocks of Auchincruive Climax, selected from seven different sources in this country and overseas were observed for incidence of yellows or streak. Out of 375 plants, only 4 showed no yellows throughout the season. A report on the effects of transient yellows and streak in Climax was published (E.429).

The maiden crop of a small scale trial of two strains of Royal Sovereign supported previous evidence that the S231 strain cropped more heavily than the S26 strain. Both clones are virus free. The plants show no other differences.

In two-year-old replicated trials, Cambridge Premier, Vigour and Regent all cropped more heavily than Huxley. Regent, like Mme. Lefebvre, was badly affected by Strawberry Mildew on both leaves and fruit.

A report of a preliminary tasting trial with strawberry and raspberry varieties (E.432) showed that Royal Sovereign M48, Climax, and Perle de Prague were the most palatable of those tested.

Raspberries.—A disease survey, made on raspberry canes during 1954 5 winter on the two main trials, showed marked varietal differences in the amount of damage caused by both *Botrytis* and Spur Blight. Detailed examination of samples of fruit throughout the picking season showed that a surprisingly high percentage of fruits were damaged by wind injury, raspberry beetle, or *Botrytis* (in

that order). Differences were found between varieties ; but observations will need to be extended over several seasons before conclusions on varietal susceptibility can be drawn.

Two of the raspberry trials are now in their seventh season of cropping and the third has given nine crops. Yields were good, with Seedling T top, closely followed by Promise, both giving approximately 5 tons to the acre. In the seven-year-old trial of New Zealand and Amos Lloyd George versus Promise and Exploit, both strains of Lloyd George are now falling back markedly in yield and the fruit of both, never really good in this trial, has become small, crumbly and uneconomic, presumably due to virus.

Loganberries.—Plants of five promising strains of loganberry are being propagated by tip-layering for field trial, and are being concurrently tested by the Plant Pathology Section, together with plants of other strains, with a view to making ultimate selections for trial on the basis of freedom from viruses possibly related to the decline of planting stocks of this crop.

Blackberries.—A clone of the Thornless Evergreen blackberry from Oregon is being raised for a trial to compare the yield, fruit quality and ease of handling of this new variety with those of the related thorned form of *R. laciniatus* usually known in England as the Parsley-leaved Berry.

Blackcurrants.—Results were published from a seven-year trial of seven varieties (E.427).

Propagation and maintenance of stocks

Strawberries.—Forty clones have been maintained as potted stock plants in insect proof houses. Sixteen virus-free clones and thirteen carrying mild viruses were propagated in gauze houses. Three isolated field runner beds contained (*a*) Royal Sovereign, (*b*) ten other virus-free stocks and (*c*) fourteen virus-tested stocks carrying mild viruses. Runner bed (*b*) included some plants of Talisman, which grew and runnered vigorously. Plants of various varieties were supplied in autumn 1954 to the National Fruit Trials, for replicated cropping tests.

Breeding

Raspberries.—The self-bred progeny of Romy, mentioned in last season's report, has shown considerable segregation in time of producing its autumn crop but is apparently pure-breeding for the ability to flower on the tips of the first year canes. A second family of similar origin was planted in 1955 to increase the chances of finding valuable segregates. The two F_2 families of *Rubus occidentalis* (black raspberry) × red raspberry yielded few plants of commercial interest. Two promising plants were selected from the cross Boysenberry × Exploit ; these will be propagated and also backcrossed to the red raspberry parent. The Lloyd George × *R. palmatus* material was backcrossed to Lloyd George ; only four plants were obtained but these show considerable vigour. A large family, derived from open pollinated seed of the original F_1 plants, has been planted in the hope of finding fertile tetraploids. A second F_1 of Lloyd George × R. *palmatus* was made and some 230 of these plants were treated in the cotyledon stage with 0·6 per cent colchicine.

The 39 families raised this year include a number of second and third generation selfs, several of which show little or no loss of vigour.

A start was made, in collaboration with the Entomological Section, in investigating the inheritance of resistance to *Amphorophora rubi*, the main vector in the transmission of raspberry viruses. The object of this line of work is to find out if it is possible to build up immunity or near immunity.

A number of hybrids between purple raspberries and Lloyd George and Norfolk Giant derivatives have been planted out.

A valuable collection of red, purple and black raspberry selections was obtained through the kindness of Professors G. L. Slate and G. F. Waldo of Geneva, New York, and Corvallis, Oregon, and the collection of potentially valuable wild *Rubus* species was also augmented during the year.

Preliminary canning trials were carried out on most of the propagated selections and small scale jamming tests on single plant selections.

Currants and Gooseberries.—Selection was continued on black currant seedlings and a number of new gooseberry hybrids and self bred lines were sown. The 1954 hybrids with spineless gooseberry varieties have not yet flowered, neither have the interspecific hybrids which were treated with colchicine.

Cytology.—A study of the cytology of some interspecific *Ribes* hybrids was begun. Further investigation into the cytology of the sport of M.XIII, described in the Annual Report for 1953 (pages 121–2) has shown this to be a chimaera with a diploid epidermis surrounding a core of tetraploid tissue.

Cultural measures

Strawberries.—The time-of-manuring trial was concluded after its third crop. Differential nitrogen treatments with and without irrigation were begun on 1-year-old Royal Sovereign plots. This trial was severely affected by Strawberry Mildew but the mean cropping rate over all treatments

reached 4 tons per acre. There was relatively little *Botrytis* rot, and beetle damage was less severe than last year. Captan sprays applied to most plots led to some controversy over possible fruit taint.

Black currants.—Results were published from two black currant pruning trials (E.428). In the second trial, bushes pruned immediately after picking gave a 12 per cent increase in crop when compared with bushes that were winter pruned. Application of nitrogen after picking instead of in spring had no marked effect on yield.

Frost damage investigations

In 1955 the only damaging frosts, at East Malling Research Station, occurred during the third week in April. The minimum screen and grass temperatures (27° F. and 23° F. respectively) were recorded on 25th April. Blossom development had been retarded by the cold spring and frost damage was not heavy. Bramley's Seedling suffered most damage among apple varieties, being at that time in the early green cluster stage. Some pears were damaged ; but damage to plum and cherry buds was negligible. Among soft fruits, raspberries and blackcurrants suffered most frost damage but the final crop was not much reduced.

A record was made of frost damage to blossoms of Cox's Orange Pippin on M.XII in one of the cultural and manurial trials. In this one year blossoms at the same stage of development from the cultivated plots suffered more damage to their styles than those from grass plots. No difference in damage was found between fertilizer treatments. In this trial the experimental plots are randomized and are 40 feet square, it thus being unlikely that the minimum temperatures over the cultivated and grass plots differed to any great extent.

In the laboratory, experiments were started on the relative winter hardiness of two raspberry varieties in relation to their rest period. Artificial freezing of plants was combined with an anatomical and histological study of the frost damage symptoms.

Experimental work was begun on physiological factors associated with frost resistance of fruit blossom. Hardiness was induced artificially in potted fruit plants and the water relationships of the flowers were examined. A study was also made of the factors associated with differences in natural hardiness, where such differences were known to occur, i.e., between varieties or between different stages of development of the same variety.

Investigations were continued on the relative spring frost resistance of two pear varieties at different stages of development and of ten apple varieties at full bloom. Sixty-four of the apple seedlings bred for possible spring frost resistance were also tested.

Modifications of the system of air circulation in the frost chamber were made in an attempt to improve the temperature distribution inside the room.

A paper was published on the effect of soil compaction on incidence of frost (E.430).

Mycorrhiza

The growth of mycorrhizal and non-mycorrhizal apple leaf bud cuttings, apple stem cuttings and cherry stem cuttings has been compared. For the third year in succession mycorrhizal apple leaf cuttings and seedlings, grown in autoclaved soil in open pots in a greenhouse, have grown more steadily over a longer period, and have produced taller and heavier plants than the non-mycorrhizal ones.

A paper describing the fructifications of an *Endogone* sp. and inoculation experiments in which these fructifications caused mycorrhizal infection in strawberry roots is in the press.

Walnuts

In spite of the good summer walnuts cropped fairly lightly this year, due to few flowers being produced and poor weather during the blossoming season.

Horticultural meteorology

Wind studies in orchards with wide and close-spaced trees were continued this season with increased replication of anemometers to overcome some of the variation that had been found between these instruments.

The usual meteorological observations have been continued at East Malling and Throwley. Special frost forecasts have again kindly been supplied by the Meteorological Office.

Publications During the Year

E391 Preston, A. P. (1955). **Higher yields with new apple rootstocks.** *Fruit World*, **56**, 27–9.

E410 ——— (1954). **Effects of fruit thinning by the leaf count method on yield, size and biennial bearing of the apple Duchess Favourite.** *J. hort. Sci.*, **29**, 269–77.

E412 ——— (1955). **Apple rootstock studies : Malling-Merton rootstocks.** *J. hort. Sci.*, **30**, 25–33.

E417 GREENHAM, D. W. P. (1954). **Orchard soil management.** *The Fruit Year Book* 1955, 32–42.
E418 GARNER, R. J., and HATCHER, E. S. J. (1955). **The influence of source and growth substance on the behaviour of apple and plum cuttings.** *J. hort. Sci.*, **30**, 116–28.
E419 ——— (1955). **Cherry tree production.** *Sci. hort.*, **11**, 56–9.
E420 PRESTON, A. P. (1954). **Thinning apples.** *The Fruit Year Book* 1955, 28–31.
E423 TYDEMAN, H. M. (1955). **Descriptions of the Malling apple rootstocks.** *Rep. E. Malling Res. Sta. for 1954*, 64–6.
E424 WAY, D. W., HATCHER, E. S. J., and GARNER, R. J. (1955). **Aspects of rootstock propagation. III. Experiments with root cuttings.** *Rep. E. Malling Res. Sta. for 1954*, 67–72.
E425 HATCHER, E. S. J., and GARNER, R. J. (1955). **The production of sphaeroblast shoots of apple for cuttings.** *Rep. E. Malling Res. Sta. for 1954*, 73–5.
E426 MOSSE, BARBARA (1955). **Symptoms of incompatibility induced in a peach by ring grafting with an incompatible rootstock variety.** *Rep. E. Malling Res. Sta. for 1954*, 76–7.
E427 PRESTON, A. P. (1955). **A black currant variety trial.** *Rep. E. Malling Res. Sta. for 1954*, 78–81.
E428 ——— (1955). **Pruning trials with black currants.** *Rep. E. Malling Res. Sta. for 1954*, 82–5.
E429 WILSON, DOROTHY J. (1955). **The effects of transient yellows and streak in Auchincruive Climax strawberry.** *Rep. E. Malling Res. Sta. for 1954*, 86–7.
E430 SLATER, C. H. W., and RUXTON, J. P. (1955). **The effect of soil compaction on incidence of frost.** *Rep. E. Malling Res. Sta. for 1954*, 88–91.
E431 MACNEILL, M. M. (1955). **Some factors affecting the culture of apple trees in pots under glass.** *Rep. E. Malling Res. Sta. for 1954*, 92–5.
E432 WAY, D. W., and FREEMAN, G. H. (1955). **Preliminary tasting trials with strawberries and raspberries.** *Rep. E. Malling Res. Sta. for 1954*, 96–8.
E433 TROWELL, G. F. (1955). **Weather conditions during 1954.** *Rep. E. Malling Res. Sta. for 1954*, 99–101.
E435 PRESTON, A. P. (1955). **The development of the Malling-Merton apple rootstocks.** *The Agricultural Review*, **1**, 42–6.
L23 PEARCE, S. C., and GREENHAM, D. W. P. (1955). **A short history of Research Station land in the parish of East Malling.** *Rep. E. Malling Res. Sta. for 1954*, 54–63.

II. STATISTICS AND RECORDS

By T. N. HOBLYN and S. C. PEARCE

Design and analysis

With the completion of the main planting programme at existing Experimental Horticulture Stations, the number of trials designed outside the Station has fallen off, though further trials for the National Fruit Trials at Brogdale, e.g., pears, plums, raspberries, and strawberries, have been prepared, and our collaboration with the Scottish Horticultural Research Institute has continued. Eleven trials and demonstrations have been planned for the N.A.A.S. in the provinces.

The acute shortage of land on the Research Station suitable for experiments in which it is essential that the trees remain until full bearing is reflected in a reduced number of large scale plantings. Nevertheless, quite a large number of intensive trials were planned, half of which were on material previously planted, thus involving either the changing of treatments or the use of areas planted for calibration. In this last connexion, it is intended during the next year or so to make good a deficiency of established fruit plants, other than apples, for experimental use when required. To this end plans have been made and the plants are being prepared for so-called calibration areas of raspberries ($1\frac{1}{2}$ acres to be planted 1955–56), black currants (2 acres in 1956-57), and pears ($3\frac{1}{2}$ acres in 1956-57) ; it is intended to add an acre of plums later.

If there have perhaps been fewer new trials designed, the number of those already planted that have yielded results requiring analyses has risen considerably. This was largely occasioned by trials conducted outside the Station for the design and analysis of which the Section is responsible. Such experiments accounted for one-fifth of the statistical analyses that were completed.

Some idea of the amount of experimentation in progress may be obtained from the list of field trials in progress in 1955 and for which there are project files in the record office. Apart from any work in the laboratories or the greenhouses, there are now over 250 such trials in progress on the Experimental Farm, on the results from any of which statistical analyses may have to be carried out from time to time. Experimental Horticulture Stations alone account for 77 more trials.

Many of these experiments are only just starting to yield results; thus Luddington with some 70 acres of fruit planted between 1951 and 1955 yielded its first substantial crop of soft fruit this year. So it must be expected that the work of analysing the results will materially increase in future years.

Statistical research

Methods of experimental design

Work has continued on the general survey of designs that make possible the changing of treatments ; the mathematical aspects have been particularly studied, including the classification of these designs and the conditions for their existence. In the course of these studies some apparently new types of partially balanced design have been discovered, and a report prepared.

Methods for using parts of a tree, e.g., branches, as experimental units are still being explored.

With the help of a post-graduate student, attention has been given to some of the assumptions underlying the use of transformations.

The limitations of trials that can be done once and in one place only have been realized here for many years. The difficulties associated with such trials, which are often the only ones that can be done on perennial crops, were explained in a paper prepared for the Biometric Symposium in 1955 summarizing the problems of experimentation with long-term crops.

Statistical studies in biology, including measurement problems

In the past, in studies of growth analysis, attention has been concentrated on increments of growth over a whole season. In collaboration with the Plant Physiology Section samples of apple rootstocks have been examined at various times throughout the season, and the relationship of increase in dry weight to various factors studied. This has given rise to a number of statistical and mathematical problems, especially in partial regression, and a new method of measuring the areas of apple leaves has been devised and tested (see page 104).

Attention has been directed especially to the use and meaning of branch girths (see page 76) in the measurement of apple trees. Methods have also been evolved for the rapid measurement of the extension growth.

A study has been made of the extent to which variations in the size of apple trees are connected with changes in soil acidity (see page 80).

Methods have been worked out for testing the ability of persons to detect and identify flavour

characteristics of fruit, and, by their use, a panel has been selected, which has already been employed in studies of apples and strawberries (see page 86).

Historical studies

The history of that part of the Station's land that lies in East Malling has been described (L23), and attention has now been directed to that within the parishes of Ditton and Aylesford.

Field trials

The detailed recording of the apple uniformity trial has continued though, because of the size of the trees, measurement of extension growth in the winter of 1954-5 was perforce curtailed.

In the trial on restoring the uniformity of land, carried out in collaboration with the Pomology Section, the first year's growth of the first series of indicator plants (apples on M.VII) gave very indecisive results and it was not clear how far, if at all, uniformity had been achieved. Accordingly these plants were grown on for a further year, and there is good reason to hope that the additional records will make the position plain.

Publications During the Year

M22 Hoblyn, T. N., Pearce, S. C., and Freeman, G. H. (1954). **Some considerations in the design of successive experiments in fruit plantations.** *Biometrics*, **10**, 503–15.

M26 Freeman, G. H., and Hall, Margaret J. (1955). **Some statistical aspects of a recent series of Fruit Tree Red Spider Mite control trials.** *Rep. E. Malling Res. Sta. for 1954*, 102–6.

III. PLANT PHYSIOLOGY

By H. W. B. BARLOW

Collaboration has continued between the Plant Physiology Section and the Research Institute of Plant Physiology under Professor F. G. Gregory, and the following report includes work of the latter's staff carried out at East Malling.

Studies of growth and form in fruit trees

Field experiments on the interaction of rootstock and scion

This year only routine measurements were made on the main experiment analysing the growth of composite trees of four rootstock varieties, together with observations on flowering and fruiting behaviour. The final harvest of this experiment is due in 1956, by which time the trees will have completed six years of scion growth.

Measurements have also been continued on the experiment investigating the effect of pruning treatments and deblossoming on the growth of four commercial scion varieties of apples on M.IX and M.XVI. Some trees this year bore crops too heavy for their branches with consequent breakage, and although this may be the logical result of the experimental treatments, it complicates the handling of the data very considerably, and introduces quite unwanted ' pruning ' treatments.

Last year a brief description was given of an attempt to grow shoots in the absence of root limitation, and roots in the absence of shoot limitation ; its success with apples led, this year, to an experiment on a larger scale with certain plums which were available on their own roots. Shoot grafts were made of Warwickshire Drooper, Victoria, Large Sloe E.328, and Dwarf Sloe E.329, on to some well-established plum rootstocks, of which the stems had been very heavily cut back ; root grafts were made on to intact trees. The root grafts have not yet been examined, but shoot growth was very vigorous, and confirms last year's tentative conclusion that it is possible for a shoot system to attain a much higher rate of growth than can be achieved when it grows on a root system that has developed in equilibrium with it.

An interesting leaf variegation, due to a chlorophyll-deficient band in the mesophyll, appeared in all shoots of the experimentally grafted Dwarf Sloe, though absent from the parent bush.

Growth of young trees under particular conditions

The techniques providing certain special conditions of growth have themselves been further investigated : the mist culture system has again been improved, and has been relatively trouble-free this year, while the more orthodox solution culture method has resulted in very satisfactory growth. That this may have been largely due to sinking the containers in the ground and thereby keeping the solution cooler was indicated by work described on page 101 of this Report.

One- or two-year-old simple or worked apple trees have been grown under these and other particular conditions for detailed growth studies.

The effect of ' size at planting ' and ' degree of cutting back ' on the subsequent rate of growth was observed on five apple rootstock varieties in mist culture. Rooted shoots were specially selected from the stoolbeds for uniformity within two size grades, ' normal ' and ' very small ' ; these were tipped to the same relative extent, while two further treatments were applied to the normal sized shoots, being cut back by $\frac{1}{3}$ or $\frac{2}{3}$. The data so far acquired indicate that there were marked varietal differences in growth, and while the very small plants grew faster than the normal ones, the relative growth rates were not materially affected by pruning treatments. Measurements were also made of root growth, with particular emphasis on the response to temperature changes.

Data for growth analysis were obtained from four rootstocks of varying vigour (3423, M.IX, MM.109 and Crab C) grown in soil in pots. These data are being treated by methods worked out in collaboration with the Statistics Section, which have led already to some interesting conclusions. Use has been made of double regressions of increment in dry weight over a given period on the mean leaf area during that period, and the dry weight at the start of it. This technique has made it possible not only to confirm the relationship suggested last year between net assimilation rate and relative vigour, but also to detect at least one other factor which, although not yet identified, is clearly important in determining the characteristics of a rootstock.

Worked and unworked apple rootstocks were also grown in solution culture, and detailed records taken of stock and scion growth, leaf area, and nutrient uptake.

In the course of this work the need for a quick method of measuring leaf areas on the plant came

very much to the fore, and a method has been evolved, in collaboration with the Statistics Section, which appears to be an improvement on existing methods. This is described in Part III of this Report (page 104).

Allowing a number of primary shoots to grow out from a pruned stem, or restricting the growth to a single shoot, may affect the total amount of growth made. Experimental treatments along these lines are being applied to various woody plants ; this year blackcurrants were grown in solution culture, and limiting the number of primary shoots reduced the total growth made by the plant. This contrasted with the behaviour of willows last year, which more or less compensated for restriction of the number of primary shoots by extensive secondary branching, and it is probable that the type of response depends on the degree of apical dominance in the plant considered.

Growth of individual shoots

The factors controlling internode extension in apple shoots are being investigated by two methods in parallel : the evaluation of the part played by leaves of various ages by observing the effect on internode length of removing leaves at particular stages, and the correlation of shoot elongation with the growth substances present in ether extracts of stem and leaf.

The results of experiments of the former type up till last year are summarized in a paper in Part III of this Report (page 89), and this year two further experiments have been conducted to clarify some of the issues raised there, particularly the effect of leaf removal on the area of the remaining leaves, and the rate of production of new leaves from the tip.

An experiment was carried out to provide extracts of shoots treated by decapitation or defoliation on a somewhat complicated time-table designed to smooth out the natural fluctuations in growth substance content which marred the similar type of experiment mentioned last year. The growth substances in these extracts are analysed by means of chromatographic separation and assay by the coleoptile straight growth test. Preliminary results are encouraging.

The results of the work on transport of natural auxin in isolated segments of woody shoots have been collated in a paper which is at press, and work has been continued this year on the subject with particular reference to the movement of auxin in the shoot while still attached to the plant. In these studies the coleoptile curvature test is used.

Coleoptile section extension

While the extension of the coleoptile section is, in this laboratory, merely the means of analysing the growth substances present in the ether extracts alluded to above, this year some research had to be devoted to a study of the time-course of extension of sections of various physiological ages, in order to interpret correctly the results of the routine tests. The results of an extensive experiment (carried out last year) and a number of ancillary ones this year, have been collected for publication.

Some additional work has been done on the effect of temperature on the response of the coleoptile section to added growth promoter, which has a practical bearing on the conduct of the straight growth test.

Vegetative propagation

Following up last year's work, experiments in collaboration with the Pomology Section were carried out on the storage of hardwood cuttings of four plum and two apple rootstocks during the winter. The cuttings were kept in a series of compartments in which a basic minimum temperature of 45° F. was maintained at 8 ins. depth in the peat-sand medium by thermostatically controlled low-voltage heating elements. An additional 10° F. was provided for limited periods. The total capacity of these beds was 20,000 cuttings.

Such storage treatments resulted in considerable benefits to the rooting of such refractory material as Crab C cuttings, and even with a readily rooting variety, provided a valuable insurance against the adverse effects of a cold autumn. It should be stressed, however, in view of the marked varietal differences observed this year, that care must be taken to avoid over-treatment, as the sensitized cuttings may be vulnerable to transfer to open soil.

Abscission

The experiment carried out last year in collaboration with the Pomology Section on the apple variety Sunset to determine the effect of hand-thinning on the production of the final crop, was repeated this year ; the effect of thinning early (13, 23 and 33 days after full-bloom) was very marked, not only on size of fruit, but on maturity. The records of fruit drop, made at frequent intervals throughout the season, have not yet been examined.

Spray damage

The principal item of work this year was to follow the change in susceptibility to damage by copper sulphate solution of leaves of M.II rootstocks throughout the season. The results suggested that there are three ways in which the leaf reacts to copper sulphate. First, at concentrations lower than about 0·8 per cent copper sulphate, there is little damage (less than 20 per cent) and the leaf is insensitive—i.e., there is a small change in the amount of damage for a given change in concentration of solution applied. Second, at concentrations greater than 1 per cent damage is severe (more than 40 per cent), but there is again a small change in amount of damage for a given change in concentration. The third type of reaction may be a transition between the other two, and is characterized by a large change in damage for a small change in copper concentration. This third type was present exclusively during July and August, while at other times two of the three or all three types were observed. This complex response of the plant to copper makes it difficult to express changes in susceptibility simply, or to compare different varieties except by making a number of determinations during the year.

Such comparisons were in fact made of the response to copper sulphate of leaves of seven apple varieties ; all showed a similar pattern of behaviour, the most surprising feature being the almost identical susceptibility of Cox's Orange Pippin and Worcester Pearmain growing on M.II rootstocks ; on M.IV both were more susceptible, Cox more so than Worcester. Shading M.II rootstocks markedly reduced their susceptibility to copper toxicity.

In collaboration with the Pomology Section, in an experiment on the use of copper sulphate to defoliate Laxton's Superb apple trees, measurements were made of damage five days after spraying to determine how far this reflected the final degree of defoliation, and the resulting harm to the tree.

Fruit splitting in cherries

Following the use in America of dilute sprays of α-naphthylacetic acid (NAA), the work on controlling splitting in cherries has again been taken up. This year only a small-scale trial was undertaken on three varieties with one, two or three dates of application of 1 p.p.m. NAA. There was severe fruit cracking this year, and the sprays were only very slightly effective in reducing its incidence. Next year more times of application will be covered, and some attempt will be made to discover the possible mode of action.

Publications During the Year

F77 Barlow, H. W. B., Dicker, G. H. L., and Briggs, J. B. (1955). **Studies on control of Apple Sawfly, *Hoplocampa testudinea* (Klug). II. Effect of sprays on fruit drop and yield.** *Rep. E. Malling Res. Sta. for 1954*, 107–14.

F78 Barlow, H. W. B., Hancock, C. R., and Lacey, H. J. (1955). **Some observations on growth inhibitors extracted from woody shoots.** *Rep. E. Malling Res. Sta. for 1954*, 115–21.

F79 Vyvyan, M. C. (1955). **Interrelation of scion and rootstock in fruit-trees. I. Weights and relative weights of young trees formed by the reciprocal unions, as scion and rootstock, of three apple rootstock varieties : M.IX, M.IV, and M.XII.** *Ann. Bot., Lond., N.S.*, **19**, 401–23.

F82 Ruck, H. C., and Gregory, F. G. (1955). **Mobility of manganese, magnesium and potassium in leaf tissues.** *Nature, Lond.*, **175**, 378.

IV. BIOCHEMISTRY

By W. A. ROACH

Analytical methods

Micro-chemical methods

A slight modification in the magnesium method has been introduced to improve precision. Studies of the methods for the determination of iron and of manganese have been continued.

Spectrographic methods

The flame method has been in routine use for the determination of potassium, calcium, manganese, and copper ; no further modification has been found necessary.

Work on the determination in small samples of trace elements such as zinc, molybdenum, nickel, etc., was suspended, as was that on the multi-channel flame photometer.

Work has been concentrated on the development of a *simple routine* arc method for the determination of phosphorus, potassium, calcium, magnesium, manganese, and iron in small samples. This method should be ready for routine testing in the near future.

Studies in nutrition

Analytical determination

Some thousands of samples have been analysed for potassium, calcium, manganese, and copper by the routine flame spectrographic method and the results are being studied. Clear cut differences in mineral composition in parallel with horticultural phenomena such as biennial bearing, rootstock effect, etc., are detectable, varying according to the season and from leaf to leaf on the same shoot.

Magnesium deficiency.—Work has continued along the same lines as in the previous season.

Spray culture of apple rootstock layers

Further improvements have been made in the apparatus ; growth of the plants receiving a complete nutrient solution has been even better than during the previous season. A description of the apparatus is being prepared for publication.

Four levels each of magnesium and iron supply have been studied ; experiments upon the interaction of deficiency of these two elements at different levels will be undertaken as soon as feasible.

In subsidiary experiments the tops of plants, the roots of which were maintained in spray culture using a magnesium-deficient solution, have been dipped periodically in magnesium sulphate solution to determine how far magnesium introduced through the leaves produces the same effect as when absorbed through the roots, and, in particular, how far it benefits the roots. A similar experiment has been carried out using a nutrient solution deficient in iron.

Organic constituents of fruit plants

Work on host-parasite relationships, in collaboration with the Pathology Section, has continued. The depressant action of chlorogenic acid, isochlorogenic acid, phloridzin, and arbutin on the growth of *Venturia* spp. has already been reported ; attention is now directed to the identification of other types of polyphenols present in the host plant. One group of compounds has been recognized as *p*-coumaryl quinic acids and work is continuing on other groups.

Further studies have been made on the breakdown of members of the polyphenol group by *Venturia* spp. in culture. Use has been made of the petiole injection method to commence a study of the fate of such compounds after injection ; the glycoside arbutin is transported from the injection point up to the young tip leaves.

The preparation of groups or individual members of the polyphenol fraction for use in the injection work has continued.

As stated last year, a start has been made on applying the general methods of separating the organic constituents of plants to the study of metabolic disturbances resulting from mineral deficiencies, e.g., manganese deficiency in the potato, maize, and mangold and iron deficiency in the apple. Use was made of plant injection methods to produce a normal and deficient half of the same leaf for comparison.

The preliminary evidence obtained suggests that methods of this type are capable of revealing differences in metabolic pattern, whether quantitative or qualitative, due to mineral deficiencies. Results so far are in harmony with the hypothesis that mineral deficiency causes enzymic blockage.

In collaboration with the Pomology Section some preliminary work has been done on the metabolic changes connected with breakage of the graft union between incompatible varieties of pear.

V. PLANT PATHOLOGY

By R. V. HARRIS

BACTERIAL DISEASES

Bacterial canker of stone fruits

Cherry

Studies of the effects of foliar sprays on the inoculum potential of the leaves as measured by the numbers of *Ps. mors-prunorum* on the leaf surfaces, were continued. Streptomycin sprays applied in the autumn of 1954 resulted in only a slight reduction in the inoculum potential, but induced a marked reduction in the number of canker infections as recorded in May, 1955.

A Bordeaux mixture spray (6 : 9 : 100) applied at white bud in Spring, 1955 had little effect on leaf infection and none on the numbers of bacteria present on the leaves. Streptomycin sprays applied during the blossom period reduced leaf infection considerably, and temporarily depressed the numbers of leaf surface bacteria. There was a rapid ' build up ' however and within a few weeks these numbers approximated to those on the unsprayed trees. Autumn sprays of streptomycin decreased the inoculum potential, but not to the same extent as ' low ' strength Bordeaux mixture sprays.

Commercial spray trial. On young Napoleon cherry trees the cumulative effect on the incidence of Canker of a series of Bordeaux spray applications, applied in the spring and summer of 1954, was recorded in June, 1955. A white-bud application alone showed no control, but when coupled with a petal-fall application infection was reduced by nearly half. Little further improvement followed the addition of one or two more foliage sprays at intervals later.

Plum

The trial of spray programmes for the control of the disease in Victoria plum at the N.A.A.S. Experimental Horticulture Station at Luddington was continued. The data for 1955 season are not yet available, but the 1954 results show that the foliage sprays of Bordeaux mixture reduced the incidence of the leaf-spot phase, but had no measurable effect on the incidence of stem canker.

Cauliflower of strawberry and related diseases

Experiments were continued in collaboration with the Entomology Section (see VI, page 45). Using surface sterilized eelworm inoculum, eelworms were successfully cultured on *F. vesca* seedlings under completely aseptic conditions. By this means it has been shown that certain subsidiary symptoms associated with both eelworms and *Corynebacterium fascians* in the field can be caused by the eelworm in the absence of the bacterium.

FUNGAL DISEASES

Apple and Pear Scab studies

This closely-knit collaboration with the Biochemistry Section (see IV, page 36) was developed along the lines indicated in previous reports. The culture collection was maintained under paraffin oil and was extended. Particular attention is being paid to the maintenance of pathogenicity along with mycelial characters in culture, and with methods for securing this. In the chemical, cultural, and *in vivo* studies of the factors inducing scab-resistance, quantitative estimation was added to qualitative identification in the analysis of the aromatic fractions concerned, and in the comparative study of the metabolic pattern in healthy and diseased leaves of single and contrasted varieties of apple and pear. Outstanding points emerging from the year's work are as follows :—

In chemical determinations, young leaves of the Conference pear were found to contain more of the active aromatic constituent, chlorogenic acid, than those of the less resistant Williams.

Under cultural (*in vitro*) conditions it was found that the chemical *nature* of the organic nitrogen source, as well as its *amount* in relation to aromatic constituents, is crucial. Under the same conditions it was further found that chlorogenic acid is more inhibitory in the presence of complete aromatic complexes, suggesting the importance of the relative proportions of aromatic constituents, and of synergism between them as resistance factors.

In the greenhouse studies on young trees, evidence was obtained of the translocation and persistence of the relevant aromatic compound, arbutin, in apple leaves. In parallel injection studies with differing sources of organic nitrogen it was found that glutamic acid stimulated Scab most, and the possible significance of this in the host relations of *V. inaequalis* (e.g. in differing varietal susceptibility) would seem worthy of further investigation.

Verticillium Wilt of hops

Host-parasite relations; the mechanism of Wilt-tolerance

From continued physiological and anatomical studies it has been possible to put forward tentative suggestions as to the nature of some of the mechanisms by which Wilt-tolerance may be achieved. These include, modifications of cell-wall structure in the roots tending to restrict the entry of the pathogen into the vascular cylinder ; the development of tyloses in the vessels, probably reducing fungal development but also water transport ; and a compensatory process of enhanced secondary wood production, permitting adequate water transport to be maintained. The factors determining symptom intensity would thus appear to operate in the very early stages of the host-parasite association.

Some preliminary investigations on similar lines were started on Verticillium Wilt diseases of various fruit crops, with special reference to raspberry and quince.

Production of new Wilt-tolerant varieties

The Wye-East Malling joint breeding project.—The fourth successive season in the preliminary screening programme for Wilt-tolerance and cultural qualities proceeded according to plan at both Institutes, and of 54 varieties subjected to the final intensive tolerance test no less than 44 showed Wilt-tolerance equal to or better than that of the OR55 controls. For the first time small crops of a considerable number of the new seedlings were harvested at Wye for commercial assessment of aroma and P.V. (preservative value).

Withdrawal of East Malling Seedling C2.—In view of the generally unfavourable verdicts of the large scale brewing trials of the Institute of Brewing on the crop of this seedling for three successive seasons (1952, 1953 and 1954), together with its cultural disadvantages as assessed by five years of commercial farm trials, it was decided to dis-continue its further trial and not to release it to the Industry. The five growers co-operating in the farm trials were informed of this decision and were asked to ensure that no further propagation was made and that no material was distributed.

East Malling Seedlings D1, D3, and J2 and Whitbread's 1147.—Observations were continued on 13 commercial trial plots of these varieties on 10 farms and the results were satisfactory from the disease point of view, wilt incidence being less than 2 per cent in most instances, though occasionally rising to as much as 22 per cent in a new planting. The three East Malling seedlings were included in the large scale trials of the Institute of Brewing on the 1955 crop.

The production of wilt-free stocks.—A stock of tested Whitbreads 1147 was established and was further tested and observed for minimal virus-disease status during the year. It will be ready for distribution to commercial hop propagators as one-year bedded sets in the coming winter.

The preparation of similar foundation stocks of seedlings D1, D3, and J2 also continued, to ensure that they can be available immediately a decision is taken on their release to the Industry.

Pathogenicity tests

The results of the series of tests made in the special concrete-trench equipment described in a previous report have indicated that an isolate of *V. albo-atrum* from an unusually acute outbreak of Wilt in a single plantation of the Wilt-tolerant OR55, of some years' standing, does not differ significantly in its pathogenicity from a typical ' progressive ' strain causing the usual mild symptoms in this variety. This anomalous outbreak does not therefore indicate the appearance of a more virulent strain of this pathogen and the reasons for its severity must lie elsewhere.

Two other reported cases of ' breakdown ' in OR55 tolerance were also investigated and in both the unusually acute symptoms were found to be associated with combined Wilt and Canker (*Fusarium sambucinum*) attacks.

The Section continued collaboration with Dr. H. H. Glasscock in the establishment of an N.A.A.S. *Verticillium* Pathogenicity Testing Unit at the Experimental Horticulture Station at Efford, Hampshire.

In this and in our combined testing programmes we are assisting the N.A.A.S. in maintaining constant vigilance for new outbreaks of Progressive Wilt outside the concentrated wilt area, and for possible new and more virulent strains of the pathogen.

Ecology

Isolation of Verticillium from soil.—No satisfactory direct method has so far been obtained, but the use of certain susceptible herbaceous host species proved to hold considerable promise.

Saprophytic growth of Verticillium spp. in soil.—Preliminary experiments showed that each of four parasitic species tested is capable of some growth in unsterilized compost. In this comparative series the hop pathogen came last in order of vigour of growth. Unlike the other three species, moreover, *V. albo-atrum* produced no resistant resting ' dark mycelium ' in the soil, but its

sporulation was more profuse. These observations apply only to the John Innes compost used, and the effect of varying soil type is probably of great importance, and remains to be investigated directly. Experiments on the effect of various cover crops on the spread of *V. albo-atrum* are in progress.

Experiments were also started on the conditions determining the time of survival of the hop pathogens in soil free from host-plant roots and also on the importance of size and concentration of inoculum on infectivity, and these are yielding results of considerable interest. Thus on particle size it was shown that 40 per cent successful infection of tomatoes occurs from inoculum fragments of size less than 0·25 mm. at a concentration of 1 per cent. Thus wind-borne ' dust ' particles could be important agents in the spread of the disease, and such particles have an infective life in soil of at least three months.

Infection by conidia.—In view of the demonstrated free production of conidia by *V. albo-atrum* in soil, small-scale inoculations were made with water suspensions of conidia and other diffusible material with positive results indicating the importance of this form of inoculum in the infection of undisturbed hop-roots.

Host-root studies.—Further experiments were also started on the importance of host roots in epidemiology and on the effect of tolerant varieties on soil infectivity.

Alternate hosts.—An extensive investigation by direct inoculation was opened on common hop-garden weeds as possible alternate hosts of the pathogenic *Verticillium* spp. in the course of which *V. albo-atrum* was re-isolated from groundsel (*Senecio vulgaris*), and surface colonization was observed on roots of *Chenopodium album*. Following these results plants of both these weeds were collected from hop wilt sites and *V. albo-atrum* was successfully isolated from a small proportion of each. It was further observed that infected groundsel plants showed no well defined symptoms although the pathogen rapidly invaded the aerial tissues. An experiment to investigate the effect of groundsel cover on the survival of the pathogens is in progress.

Collar Rot of Apple (*Phytophthora cactorum*)

The first season's work in this new investigation, stemming from recently identified cases on Research Station plantations, was concentrated on preliminary isolation work ; a comparison of these local cases with reputed cases in other counties ; a study of the growth of the pathogen in soil ; pathogenicity tests of isolates ; preliminary studies in varietal and stock susceptibilities ; and direct control measures.

Trials of methods for direct isolation from soil are giving promising results, but isolation from trunk lesions remains a most uncertain process. Successful isolations, however, were obtained from orchard trees in Kent (East Malling), Sussex, Essex, and Worcester. These were checked by re-inoculation tests. The isolates from East Malling and from Worcester were highly pathogenic, girdling 2-year Cox trees within four weeks of inoculation. Both Worcester Pearmain stems and M.II stocks showed resistance to these strains. Curative measures in a Sussex orchard (frequent examination and excision of lesions by bark-scaling) proved almost entirely successful ; of some 500 trees scraped only 20 have been lost.

VIRUS DISEASES

Work during the year on all our crops (fruit and hops) was divided, as in previous years, between closely interrelated fundamental studies of the viruses and of their natural vectors and vector relations, and applied research, consisting of the production, maintenance, and development of virus-free planting material of leading varieties (stock and scion sources in the case of the tree fruits). In the former we benefited greatly from discussions with numerous visiting overseas workers, both from the European mainland, and the American and Australasian continents, and by valuable assistance from two short term post-graduate students attached to our staff, Mr. Jordovic, a United Nations F.A.O. Scholar from Yugoslavia (6 months) and M. Geo. Morvan from France (2 months). The creation of permanent facilities for organized European co-operation in the study of the tree-fruit virus diseases was carried a stage further at the Second Symposium of workers held at Wageningen, Holland, in August. A small European working committee was set up to collect and collate information from the various interested countries, to put forward recommended lists of common indicator hosts, and to implement arrangements for further meetings at centres having suitable experimental material. It was also decided, on the Station's invitation, to hold the next meeting at East Malling in July, 1956.

On the applied side, considerable progress was made in the production of foundation planting material of apples, pears, cherries and plums (see also pages 115 and 151) and of strawberries in co-operation with the Ministry and the Nuclear Stocks Association Ltd. In hops, also, foundation stocks of new

Wilt-tolerant varieties were tested for freedom from Nettlehead and for minimal Split Leaf Blotch with a view to introduction under the recent A Plus Certification scheme of the Ministry.

Research on the fundamental side has continued to follow the general pattern indicated in previous reports and points of outstanding interest are indicated under the relevant crops below.

Fruit Virus Diseases

Apple viruses

Cross transmissions from plum to apple and from apple to peach suggest the probable identity of Apple Mosaic and Plum Line Pattern, and the results of a field-trial, with Apple Mosaic show that this virus depressed the yield of Cox and Allington by over 30 per cent. A die-back of Cox and Bramley frequently associated with ' Star-cracking ' of the fruit proved to be graft-transmissible.

Pear viruses

Improved indexing methods for the differentiation of pear viruses have been devised and an undescribed disease, ' Vein-yellowing ', was graft-transmitted.

Cherry viruses

In continued work on the highly necrotic ' Leaf Roll ' disease reported last year, all the varieties tested proved to be sensitive, so that the occurrence of carrier-varieties seems improbable. On this assumption the present incidence of the disease would appear to be very limited. Further indexing experiments with Rasp Leaf suggest that this disease is identical with the analogous Eckelrader and Pfeffinger diseases in Holland and Switzerland respectively. Virus-free clones of four more commercial varieties of sweet cherry were obtained and virus-free material of Governor Wood was imported from U.S.A. together with other varieties needed as indicators.

Plum viruses

Two strains of bark-split virus exhibited differing virulence towards plum varieties. The presence of Plum Pox in the neighbourhood was confirmed by our worker from Yugoslavia. Virus-free clones of some thirteen additional varieties were selected.

Strawberry viruses

A first series of cross-protection tests using aphid vectors and *Fragaria vesca* indicators suggest two types of virus strain in the virus 1 group. Variations in strain within the virus 2 and virus 3 categories have also been confirmed and with the recognition of mild forms of virus 3 the distinction between this and virus 4 becomes less clear.

In heat-inactivation work it was confirmed that virus 1 can be permanently inactivated in most plants by exposure for two weeks at 37° C. Two additional varieties were freed by this method. Viruses 2 and 3 on the other hand proved to be much less susceptible to inactivation and anomalous results with virus 4 provided additional evidence that certain of the viruses treated as such actually belong to the virus 3 group.

Rubus viruses

As a beginning to a study of the causes of the decline of loganberry planting stocks in recent years, a collection was made from both vigorous and ' degenerate ' sources of loganberry (in collaboration with the Pomology Section (see I, page 28)). Plants of the former, with one exception, induced no symptoms when grafted to a range of indicators of raspberry viruses, consisting of sensitive raspberry varieties, *Rubus saxatilis* and *R. henryi*. Plants of the latter, with one exception, induced virus-like leaf symptoms on *R. henryi* only. The exceptional plant induced no such symptoms on this indicator but itself showed leaf ' enations ' prior to grafting. The possible significance of the virus or viruses thus shown to be present in the majority of the ' degenerate ' plants has now to be determined.

Hop Virus Diseases

No insect transmissions of nettlehead were determined in vector tests with froghoppers or leafhoppers ; this year's tests were therefore confined to general screening. The serial exposure of hop plants for monthly periods showed that natural transmission of Nettlehead can occur during April, May, and June. A study of the distribution of Nettlehead virus in the crown of hop plants indicated that the virus is not always fully systemic.

From field records it was concluded that latent Split Leaf Blotch infection may be found in some of the more important varieties of hop, but a search for a sensitive indicator has so far been unsuccessful.

In extensive tests with the spring winged-migrant of *Phorodon humuli* no insect-transmissions of

mosaic were obtained after short, long or free-feeding infection feeds. Further vector-tests were made with *Aphis fabae, Macrosiphum euphorbiae,* and *Tetranychus urticae.*

Attempts to inactivate mosaic in Fuggle hop plants by heat treatment have been unsuccessful. It appears that this variety is unable to withstand a prolonged period at temperatures above 90° F., and it therefore seems unlikely that Fuggle can be freed from mosaic virus by this method.

FUNGICIDE INVESTIGATIONS

The combined insecticide and fungicide spray programme for apple trees

The current season's data from these joint trials (see also VI, page 45 and VII, page 48) confirm in the main the trends shown in the earlier years. The fungicides lime-sulphur, captan, zineb, and dispersible sulphur, hydraulically applied by hand to Cox's Orange Pippin trees twice before, and three times after, blossom each kept Scab in check, captan and lime-sulphur being slightly superior to the others in this respect. The inorganic sulphur sprays gave the best control of Mildew, and fruits sprayed with captan showed the best skin-finish.

Apple Mildew

Greenhouse screening studies

In collaboration with the Plant Protective Chemistry Section (VII, page 48), further modifications, designed to effect better temperature and humidity control, were made in the special house fitted for this purpose, and satisfactory early infections resulted. Later ones were not consistent, however, and there is room for yet further improvement in technique, more especially in maintaining a regular supply of inoculum throughout the season. Nevertheless, results in the first half of the season would justify an early resumption of chemical screening tests.

Field studies

On M.III rootstocks, used as the host in a trial to determine the influence of the timing of spring sprays against Mildew, a bud-burst lime-sulphur spray was ineffective, but one at green-cluster showed slight reduction in the number of mildewed shoots in May when compared with unsprayed controls. These were single applications unsupported by later protective sprays.

The field trial started in 1954 to compare the new organic fungicide, dinitro *sec* octyl phenyl crotonate (DNOPC), with standard lime-sulphur for Mildew control, yielded a second year's results confirming the better skin-finish of fruits sprayed with DNOPC at normal strength (0·025 per cent), both alone and when added to half-strength captan (0·05 per cent). Classified results on Mildew-control are not yet available.

Apple Scab

Greenhouse studies

Experiments were started on M.III rootstocks in pots to promote heavy infection from ascospore inoculum from dead apple leaves as a medium for testing the eradicant properties of various fungicides.

Concentrate-spraying investigations

It has been shown that dosage per acre of lime-sulphur is a critical factor in the control of Apple Scab and Apple Mildew. Thus, at paint-gun level, the effect was tested of a range of reciprocal concentrations and volumes of lime-sulphur yielding a constant dosage per acre.

Slight differences in control favoured the smaller volumes of the more concentrated material, which, when undiluted, was, however, not superior to the normal dilute material applied hydraulically. A medium volume at medium concentration gave good control but caused most leaf-scorch, though this was no greater from applications made pre-blossom than that from the corresponding $2\frac{1}{2}$ per cent lime-sulphur applied hydraulically.

The incorporation of insecticides with the lime-sulphur concentrate was further investigated on larger trees at East Malling with the collaboration of the Entomology and Plant Protective Chemistry Sections. The results of this experiment, together with those from tests of insecticide concentrates on small trees, show distinct promise that a combined spray-programme based on the use of concentrate sprays may eventually be successfully devised.

Continued assistance was given in two N.A.A.S. extension trials, in the South Eastern and Eastern Provinces respectively, and these were again limited to lime-sulphur concentrate alone.

Silver-leaf of plum

Further studies were made on the effects of fungicidal injectants on the expression of silver leaf symptoms, and on the spread and viability of *Stereum purpureum* in the wood of artificially inoculated

plum trees. Spring and early summer injections of 8-hydroxyquinoline potassium sulphate retarded the development of silver-leaf symptoms in trees inoculated the previous autumn. The volume of stained wood in injected trees was subsequently found to be significantly greater than in uninjected controls. The number of successful isolates, however, from the wood of injected trees was significantly less than from the uninjected trees. The implications of this inverse relationship between volume of stained wood and apparent viability of the fungus is being further examined. Observations on the rate of growth of the pathogen in the wood of the host are being continued.

Gloeosporium Apple Storage Rots (see also IX p. 51)

An initial experiment on the control of these storage diseases by spraying, was undertaken in an orchard of Cox's Orange Pippin at Bassett's Farm, Horsmonden, with the help and kind hospitality of Mr. H. St.G. Ralling. By arrangement with Professor P. H. Gregory we received valuable assistance in this experiment from Mr. E. J. Guthrie, B.Sc., of the Department of Botany, Imperial College. Work on the spray trial was combined with studies by Mr. Guthrie of natural sources of inoculum within this and other orchards and on its transport to the fruit, and the whole programme was planned in conjunction with the complementary research at the Ditton Laboratory and at Long Ashton Research Station. The results are not yet fully available.

Strawberry *Botrytis* Rot

Following the small screening trials reported last year, the first year's sprays were applied to a large scale experiment on Royal Sovereign strawberry at the N.A.A.S. Experimental Horticulture Station at Luddington. This is being carried out jointly with the Pomology and Plant Protective Chemistry Sections and with Long Ashton and the N.A.A.S.

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C342 Moore, M. H. (1954). **The search for better fungicides.** *Grower Annual Fruit Review*, 45–7. *Rep. E. Malling Res. Sta. for 1954*, 152–4.

C343 Posnette, A. F., and Cropley, R. (1955). **Strawberry Yellows in the variety Auchincruive Climax.** *J. hort. Sci.*, **30**, 56–61.

C344 Posnette, A. F. (1954). **The propagation of healthy fruit trees.** *Grower Annual Fruit Review*, 26–9.

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C347 ——— (1954). **Virus diseases and fruit tree propagation.** *Gdng. illus.*, **71**, 239.

C348 Jenkins, J. E. E., and Moore, M. H. (1954). **Brown Rot cankers in Merton Worcester apple.** *Plant Pathology*, **3**, 139.

C349 Crosse, J. E., and Bennett, Margery (1955). **A selective medium for the enrichment culture of *Pseudomonas morsprunorum* Wormald.** *Trans. Brit. mycol. Soc.*, **38**, 83–7.

C350 Crosse, J. E. (1955). **Bacterial Canker of stone-fruits. I. Field Observations on the avenues of autumnal infection.** *J. hort. Sci.*, **30**, 131–42.

C352 Harris, R. V. (1954). **Virus diseases and the fruit farmer.** *J. roy. Agric. Soc.*, **115**, 83–97.

C353 Talboys, P. W. (1955). **Detection of vascular tissues available for water transport in the hop by colourless derivatives of basic dyes.** *Nature, Lond.*, **175**, 510.

C354 Moore, M. H. (1955). **Spring discharge of Apple Scab spores.** *Commercial Grower*, No. 3093, 801.

C355 Legg, J. T. (1955). **The spread of Nettlehead disease and its Association with split leaf blotch virus in certain hop varieties.** *Rep. E. Malling Res. Sta. for 1954*, 128–32.

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C357 Moore, M. H., and Tew, R. P. (1955). **Greenhouse testing of fungicides against *Botrytis* Rot (Grey Mould) of strawberry and other soft fruits.** *J. hort. Sci.*, **30**, 213–9.

C358 Legg, J. T. (1955). **A combined aspirator and feeding cage for the collection and testing of insects as vectors of plant viruses.** *Nature, Lond.*, **176**, 609.

C359 Cropley, R. (1955). **The selection of virus-free clones of fruit plants in Britain.** *Sci. hort.*, 1952–54, **11**, 75–97.

VI. ENTOMOLOGY

By A. M. MASSEE

Tree fruits

Woolly Aphid : testing apple seedlings

Twenty-eight seedlings from open pollinated blossoms of trees of Northern Spy × Laxton's Superb parentage and of Northern Spy × Ben Davis, were found to be resistant last season and have been tested again this year. All the seedlings, with but one exception, exhibited the same degree of resistance as shown in the initial tests. Two hundred and twenty-one seedlings of the parentage Cox's Orange Pippin × Northern Spy have been tested for the first time ; six proved resistant to Aphid attack. A further batch of Crawley Beauty × Northern Spy seedlings were tested ; none was found to be resistant, colonies of aphids developing on each in a very short while.

In the course of these inoculations all immature stages, adults, and alate forms were used, the tests being made in the insectary.

The nature of resistance is being studied in collaboration with the Pomology Section.

Apple Blossom Weevil

Routine counts of ' capped blossoms ' on selected plots have shown no evidence of reinfestation since 1948.

Winter Moth studies

Studies of the biology of the Winter Moth (*Operophtera brumata* L.) have been concluded. The relationship between the time of hatching of the eggs and application of pre-blossom insecticide has been established. A report on this work is in the press.

Pear Psylla

It has been established that the overwintering forms and the summer generations of Pear Psylla found on cultivated pear in this country consists of only one species, namely, *Psylla pyricola* Föer. A detailed study of the biology of the Pear Psylla was undertaken both in the field and laboratory.

The field investigations were conducted on a plantation of Conference pears, three different kinds of field surveys being made regularly each week to obtain samples of populations. Data were also obtained of oviposition and hatching, and the build-up of adult populations was observed for each generation. Three generations occurred in the field in 1955, the peak emergence of the first being in mid-June, the second about the middle of July, and the third (the overwintering form) during the latter part of September.

The maximum honeydew formation was noted during the development of the immature stages of the second generation in July. The sooty black mould, *Cladosporium herbarum* Fr. (Link ex Fr.), also occurred on the leaves in July.

Detailed laboratory studies were undertaken to supplement the field records, special techniques being evolved for the study of individual eggs, nymphs and adults.

Ecological studies

In collaboration with the Plant Pathology and Plant Protective Chemistry Sections, the study of the integrated action of insecticides and fungicides on the Fruit Tree Red Spider Mite and its predators is in its third year. There is already evidence of natural control of the red spider by its main predator *Blepharidopterus angulatus* (Fall.).

Methods for estimating populations of the predators of the Fruit Tree Red Spider Mite have been tested, and techniques for following changes in the insect population are being developed.

The influence of the environment on insect development and fertility is under investigation in controlled temperature rooms.

An improved locally made mite brushing machine has been in use throughout the season.

The trial to assess the effects of fungicides on the orchard fauna at Stondon Massey, Essex, in collaboration with the Plant Protective Chemistry Section, has been continued for a fourth season ; this year a much larger population of Fruit Tree Red Spider Mite developed on the lime-sulphur plots than on captan sprayed trees.

At the Essex Institute of Agriculture, Writtle, the summer ovicides were applied for a second year in collaboration with the Plant Protective Chemistry Section ; predators are still not abundant in the orchard, but have increased since last season. Following one of the treatments, applied at

the pink-bud stage, the red spider density became so high by early August that an additional spray had to be applied.

A study was made in the greenhouse of the influence upon each other of *Typhlodromus tiliae* Oudms. and *Metatetranychus ulmi* (Koch) at various relative densities.

Observations in the field have been made on the life history of the Flat Scarlet Mite, *Brevipalpus geisenheyneri* (Rübs.).

Laboratory studies on the biology of four species of typhlodromid mites, namely *Typhlodromus tiliae*, *T. finlandicus*, *T. bakeri*, and *Phytoseius macropilis*, have been completed. The data from these studies have been related to work conducted in the field, and in addition field studies have been made on *T. umbricatus* and *Seiulus simplex*.

The feeding capacities and to some extent preferences, of the four species have been studied, the role of Phytoptid mites and some phytophagus sources of food having been considered.

Detailed studies of the ecology of predacious mites on individual fruit trees have been completed and related to similar but less extensive studies of the Fruit Tree Red Spider Mite. Attempts have been made to evaluate the effectiveness of predacious mites in controlling red spider under orchard conditions.

The immature stages of the fifteen species of *Phytoseiidae* known to occur in the south-east of England have been described. Three new species have been described together with the adult male forms of some previously-known species. The synonymy of *Kampimodromus elongatus* and *Typhlodromus vitis* with *T. aberrans* has been demonstrated.

Top and soft fruit aphids

Detailed biological studies of all species infesting apple, pear, red and black currant, and gooseberry are now nearing completion. Preliminary observations have been made on *Prunus* aphids.

Field trials of BHC and DDT at different concentrations and various dates of application have continued.

Concentrate spraying as a means of insect control

A small scale field trial has been carried out against the Apple Sawfly (*Hoplocampa testudinea*, Klug) to explore the possibility of obtaining control by applying insecticides with concentrated lime-sulphur at the rate of 3–6 gallons per acre. This investigation is being made in collaboration with the Pathology and Plant Protective Chemistry Sections.

Study of Codling Moth and Tortricid moths of the orchard

A study has been made of the Tortricid moths in orchards, particularly the Codling Moth and the Summer Fruit Tortricid, with special reference to the emergence of the moths, and of the parasites of the larvae.

Eelworms associated with top fruits

Pot trials with apple seedlings suggest that removal from the soil of Root Lesion nematodes, *Pratylenchus penetrans* (Cobb), and other potential plant parasitic nematodes is followed by a marked increase in root and shoot development. The association of similar nematodes with replanting problems in cherry and other top fruits is being investigated.

Small fruits

Eelworms associated with strawberry

Field and pot experiments have shown that infestation of strawberry plants by the Strawberry Eelworms, *Aphelenchoides ritzema bosi* (Schr.) and *A. fragariae* (Ritz. Bos), and by the Stem and Bulb Eelworm, *Ditylenchus dipsaci* (Kuhn), can be substantially reduced, but not eliminated, by the use of organophosphorus insecticides. Pre-planting dips are cheaper, safer, and more effective than post-planting sprays.

Further results of two field persistence trials with *A. ritzema-bosi* confirm that the infectivity of the soil declined rapidly within a few months of inoculation.

In collaboration with the Plant Pathology Section, sterile cultures of *A. ritzema-bosi* have been obtained on seedling *Fragaria vesca* plants. Studies on the etiological relationship of this species and *Corynebacterium fascians* (Tilford) Dowson in Strawberry disease are continuing.

In a field trial the virtual elimination of the Root Lesion nematodes, *Pratylenchus penetrans* (Cobb) and *P. pratensis* (de Man), from the soil caused a slight increase in the vigour of the strawberry plants.

Strawberry Aphid investigations

Population counts of the Strawberry Aphid (*Pentatrichopus fragaefolii* (Cock.)) have continued

on entire plants in studying leaf preference and in evaluating the efficiency of the sampling method in current use.

The rate of spread of apterae in strawberry beds is under study and, in conjunction with leaf development and trapping, an attempt is being made to follow the general movement of the wingless aphids from plant to plant.

Field trials are in progress to study the influence of spray programmes on the incidence of virus infection in collaboration with the Pathology Section.

Raspberry Aphid : testing *Rubus* species

In recent years it has been shown that raspberry varieties differ in their susceptibility to the aphid vector, *Amphorophora rubi* (Kltb.), of some of their virus diseases. In collaboration with the Pomology Section a search is being made amongst *Rubus* species and raspberry varieties for sources of resistance to this Aphid. Families of seedlings of selected parentage have been tested to provide information on the genetics of resistance.

Strawberry Seed Beetle and Allied species

The Strawberry Seed Beetle and closely allied species were again very troublesome in 1955, being widespread in the Kent strawberry growing districts.

Traps have been exposed in strawberry beds for three seasons to trap ground beetles. Considerable information has been gained by this method on the period of activity of the adults and larvae of some of the species which damage strawberry, notably the Strawberry Seed Beetle, *Harpalus* (*Pseudophonus*) *rufipes* (De Geer). A programme of soil sampling has been started to amplify and increase our knowledge.

New methods of rearing these beetles in captivity have proved successful.

A small-scale spraying trial, in collaboration with the Plant Protective Chemistry Section, showed that a miscible formulation of Dieldrin, though promising in reducing the damage, left residues on the fruit ; further work on this aspect of the problem is being undertaken.

Study of Gall Mites and Predacious Mites

Phytopid mite material has been received from Canada and elsewhere, and is being determined as time permits. A number of species of predacious mites have been studied and new species have been described.

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D288 CHANT, D. A., and MUIR, R. C. (1955). **A comparison of the Imprint and Brushing Machine methods for estimating the numbers of Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch), on apple leaves.** *Rep. E. Malling Res. Sta. for 1954*, 141–5.

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D290 COLLYER, ELSIE (1955). **Some predacious insects of fruit trees : Capsid bugs.** *Rep. E. Malling Res. Sta. for 1954*, 155–9.

D291 DICKER, G. H. L., and KIRBY, A. H. M. (1955). **Some impressions of apple orchard practices in Canada.** *Rep. E. Malling Res. Sta. for 1954*, 160–4.

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VII. PLANT PROTECTIVE CHEMISTRY

By A. H. M. KIRBY

Laboratory investigations

Insecticides

The year has been devoted to a study of procedures required for the rearing of a number of insect and mite species of economic importance, either as pests or as predators, in orchards and soft fruit plantations. This involves the provision of suitable plant food for the pest species, and, in the case of predators, of suitable prey which in turn require other suitable plant food. Thus the Mottled Arum Aphid is readily bred on broad bean seedlings and serves as prey for a number of predator species.

As most orchard insects are seasonal, the problem arises of extending their normal period of activity or of bringing them into the stage required at will. Conditions required for storage of eggs and other suitable stages are therefore being studied.

It has proved feasible to rear several species of predator on a continuous basis, and also certain aphids and mites, but it will be some time before any large-scale rearing can be assured. Several predacious mirids have been reared from first instar to adult and these have then laid eggs in apple seedlings.

Preliminary work has been carried out on assessing, in the laboratory, the toxicity of various pesticide deposits on foliage or wood to various orchard insects, and it is planned to develop this type of study next season in parallel with chemical estimations.

Fungicides

A series of 4-alkyl-2-mercapto-glyoxalidines, obtained from Dr. Alex. Lawson, were found to be non-toxic to spores of *V. inaequalis* even at 0·01 per cent.

The compound, 3:5-dimethyl-tetrahydro-1:3:5-thiadiazine-2-thione, offered in North America primarily as a soil fungicide under two code numbers, Crag 974 or N.521, gave complete inhibition of spore-germination of *V. inaequalis* and of *B. cinerea* when applied at 0·01 per cent, but inhibition was less at 0·001 per cent than that given by captan in simultaneous tests.

A number of products of oxidation of nabam with air or oxygen were tested. In general, these completely inhibited germination of spores of *V. inaequalis* at 5–10 p.p.m. but only slightly at 1 p.p.m., exceeding somewhat the toxicity of captan in a concurrent test. Against *B. cinerea*, these materials were much less effective, inhibition rarely exceeding 50 per cent even at 100 p.p.m., at which concentration captan gave 70–90 per cent inhibition. The results for *V. inaequalis* are of the same order as those of the Canadian workers for *Sclerotinia fructicola*, especially when it is remembered that their method of assay favours the fungitoxicant.

In an attempt to explain the superiority of oxine to phenylmercuric oxinate at 1 p.p.m. against *B. cinerea* in the spore germination test (see last year's Report, page 151), tests have been carried out with oxine, using water distilled twice in glass. Complete inhibition of spores of *V. inaequalis* was caused by 1 p.p.m. oxine when 0·05 per cent sulphite lye was added as wetting agent, but no inhibition was caused by the same concentration of oxine when the wetting agent was Triton X-100. This striking effect was not obtained when other toxicants (captan, dichlone, salicylanilide, J49, DNOP) were tried. Nor could the toxicity of oxine in the presence of Triton X-100 be increased by the addition of one or two proportions of copper ions.

Studies on the uptake of copper by spores of *B. cinerea* indicate that copper ions are withdrawn from dilute copper sulphate solutions very rapidly, the amount of further copper taken up decreasing with the external concentration. At low external concentrations more than 50 per cent of the copper ions may be removed, but at the levels required for fungistatic effect the increase from ED_5 to ED_{95} is accompanied by a very small increase in copper content of the spores themselves.

Phytotoxicity

The entry of copper ions into detached apple leaves from copper sulphate solutions was reported last year to occur in three stages, the first following an exponential curve and the others following linear curves of different slopes. This general picture has been confirmed, but the first (exponential) stage has been shown to vary from 20 minutes duration to very short periods indeed. It has been found that the uptake during the second stage (first linear curve) is proportional to the square-root of the external concentration, as was already known for the exponential stage. It has also been shown that a similar effect occurs in leaves on the tree, but the exponential stage may extend over a period of hours before the curve becomes linear.

In the intact plant, copper taken up by leaves is transferred from the leaf to the stem, and the amount of copper so transferred increases with the external concentration. However, proportionately more copper is retained by leaves from dilute solutions than from stronger. A method has now been developed whereby the total copper moving, even temporarily, into an intact leaf can be measured, and it is hoped to get direct comparison between the uptake of intact and that of detached leaves.

Chemistry

The main activity has been the determination of spray deposits and residues. This has involved work on the method for DDT residues ; the major source of error arises from the variability of field units (e.g., trees), but attempts have been made to reduce error in the analytical procedure. It is considered that benzene has several advantages over carbon tetrachloride for the post-digestion stages. On the other hand, cold methanol removes superficial deposits from leaves ; if this is followed by hot benzene extraction, total DDT can be estimated. Methanol usually recovers all DDT applied as a wettable powder, but benzene is required to recover much of the insecticide applied as an emulsion.

The method was used to study DDT deposits in several experiments carried out by the Entomology Section. In experiments in which single applications of 0·05 per cent DDT were made at bud-burst, mouse-ear and green cluster respectively, and samples examined one week after the final spraying, considerable differences in deposits of DDT were found. These were roughly in proportion to the amount of foliage available to receive the insecticide. Deposits of DDT from emulsion formulation on blackcurrant in April, or on blackberry in July, did not run parallel to the concentrations applied ; only 10 per cent of the total DDT determined chemically was recoverable by cold methanol from the blackberry shoots, indicating extensive penetration.

Following an attempt to control seed-eating beetles with dieldrin, studies were made of deposits on strawberry fruits. In the absence of a specific analytical method, total chlorine was estimated, giving good recoveries but rather high blanks. Initial deposits of 5–7 p.p.m. fell to less than 1 p.p.m. in two weeks. Further work is contemplated on this problem.

The compatibility of emulsions of DDT, BHC, aldrin and dieldrin with concentrated lime-sulphur is being studied, but interference by large amounts of sulphur or by emulsified solvents required special attention.

Collaborative work on estimation of mercury in compounded products has continued.

Greenhouse investigations

Apple Mildew.—Studies in collaboration with the Pathology Section continued on a suitable method of large-scale infection. The de-dutchable house was divided into two compartments, the stepwise heating control being confined to the southern half which was fitted with scrim blinds, and a fibre-board-glasswool-aluminium roof was placed in the northern half where the tower was located. A very satisfactory uniformity trial in June indicated that liability to infection decreased steadily from the first fully-expanded leaf down the shoot, but later trials suffered from infection before the plants were put into the infection tower and also from the absence of freely-sporing material in the field. An attempt to screen plants on the bench from spores by a celluloid cover led to interveinal chlorosis and to stunting.

Field investigations

Collaboration with the Entomology and Plant Pathology Sections continued in trials to assess the affects of certain fungicides, acaricides or spray programmes on orchard fauna, and also in trials concerning application by low-volume. The trial at Ryarsh, Kent, has been reported (D283).

Insecticide trials

Apple Sawfly.—A further trial was conducted on Worcester Pearmain on M.IX stock ; γ-BHC, added at 0·4 per cent as an emulsifiable formulation to neat lime-sulphur and applied at 3 gallons per acre (0·12 lb. γ-BHC per acre), gave a promising result, but the same formulation added to 1 per cent lime-sulphur to give 0·0065 per cent γ-BHC and applied by hand-lance at 250 gallons per acre (0·15 lb. γ-BHC per acre) was even more effective. However, it will be seen that the dosage per acre was greater in the high-volume treatment than in the low-volume.

Codling Moth.—No further trials have been undertaken, but a report on earlier trials appears on page 146.

Fruit Tree Red Spider Mite.—In the trial at Writtle, Essex, chlorfenson (CPCBS), applied as a 50 per cent wettable powder at 2 lb. per 100 gallons at pink-bud, failed to control the mite and respraying was necessary in August. However, two applications of chlorfenson or of chlorbenside, at 0·025 per cent active ingredient, in June, gave satisfactory commercial control in a season favourable to the mite.

A note on the 1954 pilot trial of applications of these two acaricides at pink-bud appears on page 149.

Predator studies

The trials at Stondon Massey (4th year) and at Writtle (2nd year) were continued. The ' spray-programme ' trials on the Station were also continued for the third year.

Fungicide trial

The trial on dwarf pyramids comparing a lime-sulphur schedule with schedules based on DNOPC alone or combined with captan (SR406) was continued.

Spray damage

Satisfactory growth was made by all material in the second block planted in the winter 1953–54.

Trials were continued on the first block and on the plum block. There was again no damage on either plum variety sprayed with chlorfenson or chlorbenside at 0·05 per cent in mid-May (sawfly timing) or in June (maggot timing). Bird-damage prevented any trial on gooseberry, but tests with new acaricides continued on blackcurrant at grape-stage. Trials on apple continued, including new chlorinated phenyl benzenesulphonates ; chlorotic spotting of leaves by PMC was observed for the first time on Laxton's Superb.

For the third successive year, a severe loss of crop of Conference pear has been caused by post-blossom applications of PMC. Leaf-damage, severe on Conference and Doyenné du Comice and less so on Williams' Bon Chrétien and Laxton's Superb, was also caused by other phenylmercurials including the acetate, basic nitrate, oxinate and ' fixtan ' ; the trees in this experiment were too young to give reliable crop records.

Publications During the Year

Q85 Frick, E. L. (1955). **Laboratory tests of the effects of fungicides on the spore-germination of *Botrytis cinerea* Pers. ex Fr.** *Rep. E. Malling Res. Sta. for 1954*, 149–51.

Q86 Kirby, A. H. M., and Tew, R. P. (1955). **Agricultural insecticides.** *Rep. Progr. app. Chem.*, 1954, **39**, 707–21.

VIII. SCIENTIFIC LIAISON SECTION

By H. B. S. MONTGOMERY

Information regarding fruitgrowing problems under research at the Station and the practical application of the results continues to be given widely by letter and telephone to enquirers in Great Britain and overseas. Visitors have been as numerous as ever with a total of 2,091, of whom 475 came from overseas. Many of these came during the summer months on their way to or from the International Horticultural Congress in Holland.

Members' Days, with a total attendance of 750, were held on pruning, the storage life of variously grown apples, the production of virus-free strawberries, and the interaction of sprays and insect populations. A special Governing Members' Day was arranged to mark the completion of the laboratory extensions ; in this some 70 visitors were guided round the laboratories and shown aspects of the work in progress.

Officers of the official advisory services attended rehearsals in connexion with these days. They also attended the annual two-day visit of the N.A.A.S., which was successfully held in spite of a rail strike, and the usual courses for hop and rootstock certification. The total attendance was about 240.

Two popular articles have been published and assistance given with many official bulletins and publications. The index to the Station's Annual Reports is nearing completion in spite of delays due to checking and greatly increased cross-referencing.

Members of the Section have given eleven lectures, and taken part in two ' brains trusts ', in Leicester, Essex and London as well as in parts of Kent. The exhibit at the Chelsea Flower Show concerned stock/scion incompatibility and showed some of the methods of overcoming this trouble. A special exhibit of Tydeman's Late Orange at the R.H.S. Show in February, was awarded a Lindley Silver Gilt Medal.

Science and horticultural lectures were organized for the plantation assistants as in previous years and farm walks on both the research station, and growers' holdings, for the research staff.

Research has proceeded on the storage quality of apples (see page 51), peach culture (see page 27) and root excavations (see page 25).

Publications During the Year

T53 Montgomery, H. B. S. (1955). **Fruit abstract on costs of apple growing on mixed farms.** *NAAS Quarterly Review*, No. 27, 116–9.

T55 ——— (1955). **Fruit abstract on pollination and fruit setting.** *NAAS Quarterly Review*, No. 29, 213–4.

T56 Rutter, A. E. H. (1955). **Production of virus-free strawberry runners.** *The Worthing and W. Sx. N.F.U. Branch Mag.*, No. 7, 269–70.

IX. FRUIT STORAGE INVESTIGATIONS IN COLLABORATION WITH DITTON LABORATORY

By H. B. S. MONTGOMERY

Apple manurial trial

A heavy crop of Cox's Orange Pippin on the manurial trial enabled a further series of storage comparisons to be made at 37° F., as in 1953–54, and at 32° F. The results obtained showed that both internal breakdown and fungal rotting were very greatly reduced by swards and that applied nitrogen counteracted this effect to some extent. Applied potash in general reduced breakdown but increased fungal rotting at 37° F. Less striking effects were observed with some other treatments.

The data are being considered in the light of chemical analyses carried out by the Ditton Laboratory ; the results support the conclusions of some previous workers that fungal rotting is low when the content of nitrogen in the fruit is low, and indicate that rotting was low also when the content of phosphorus and ascorbic acid was high.

Cell size was determined in the cortical tissue of samples of five apples from each of the experimental trees. The variability from fruit to fruit was high but the cells were slightly smaller in fruit from trees in grass without nitrogen than from the other treatments.

Soil management trial

Storage comparisons made at 32° F. and 37° F. showed a pronounced effect of grass sward in reducing the amount of fungal rotting in Laxton's Superb apples, as compared with fruit from the arable and the straw mulch treatments. Respiration rates were determined on thirty individual fruits over a four week period by the Ditton Laboratory and showed that the fruit from trees in grass had a lower respiration rate than those from the other treatments. The same effect was shown when the data for only two days in early November were examined ; use is being made of this fact in 1955 to enable respiration rates to be recorded from a larger number of treatments. No appreciable amount of breakdown or core-flush had appeared by 27th April, when the final records were made.

Other critical comparisons

In a pruning trial with Cox's Orange Pippin on M.II, the percentage of bitter pit after storage at 37° F. was higher, in this one year, in fruit from trees with established-spur pruning than in those from trees with renewal pruning. Fruit from trees pruned by the regulated method had the least amount of this trouble in this experiment. Flesh breakdown occurred extensively by the time of the first examination on the 9th February, earlier than was expected, and no clear treatment effects were found. This examination date was determined by the progress of Cox's Orange Pippins from the manurial trial, which at that time were quite free from breakdown. The trees in the pruning trial were only ten years old compared with the twenty-five year old trees in the manurial trial and the age of the trees may have contributed to this result.

Cox's Orange Pippins from a N.A.A.S. sward trial at West Peckham, stored at 32° and 37° F., failed to show any treatment effects except that fruit from trees in a wild white clover sward showed more rotting after storage at 37° F. than fruit from trees in swards of this clover with ryegrass and timothy respectively and in tumbledown sward.

No significant differences in storage behaviour were established in (*a*) Fortune apples grown under different soil-water conditions, because the light crop carried by many of the trees provided inadequate samples, and (*b*) Laxton's Superb from another trial of water regimes because there was very little rotting of any of the fruit and no internal breakdown developed by the end of April when the last examination was made.

Commercial samples

Samples were obtained from the same orchards in Kent, Sussex, Essex, and Suffolk as in 1953 4. These were stored at 32°, 37°, and 50° F. at the Ditton Laboratory and examined for wastage at intervals. There was fair agreement, as regards fruit rotting, with the results in 1954 and with the known history of the orchards. Chemical data for these samples have been obtained by the Ditton Laboratory.

In 1953 -4 the storage samples consisted as nearly as possible of 100 apples for each of the three examinations. In 1954–5 each sample was split into sub-samples each of 10 fruits and numbered in

sequence of preparation. The data obtained in this way are being examined by the Statistics Section to determine the best sample size.

Survey of commercial fruit

Very wide differences among samples of Cox's Orange Pippin from commercial sources were found after storage till January at 37° F. at the Research Station. It was difficult to relate storage behaviour to orchard conditions, especially as the majority of the samples came from trees on M.II, grown in grass sward, pruned by renewal methods, and given a normal spray programme for scab. The assistance of the N.A.A.S. has been sought in securing further information about the conditions in the orchards concerned. Where summer pruning was used there appeared to be more rotting due to *Gloeosporium* spp. Comparisons were possible between 17 samples sprayed with captan during August and similar samples that were not so sprayed and the analysis showed a significant effect of the sprays in reducing the percentage of rotted apples from 14 per cent to 9 per cent ; this degree of control is not considered good enough for commercial use.

A similar series of commercial samples has been assembled in the autumn of 1955 and stored, part in cold storage at 37° F., and part in gas storage at 38–39° F. with 5 per cent carbon dioxide and 3 per cent oxygen, for examination early in 1956.

Spraying trial against *Gloeosporium* rots

The storage samples from the simple replicated trial on growers' holdings in 1954 were examined in collaboration with staff at Ditton Laboratory during the storage period and showed an overall effect of two sprays of captan (0·1 per cent) during August in reducing the percentage of rotted fruits from 21·4 per cent to 9·7 per cent. Further experiments to provide an efficient control of these rots by spraying have been undertaken in 1955 by the Plant Pathology Section (see page 42).

Part III

RESEARCH REPORTS AND REVIEWS

GENERAL

AMOS MEMORIAL LECTURE*

THE NUTRITION OF FRUIT CROPS—A RETROSPECT

By Professor T. WALLACE, C.B.E., M.C., D.Sc., F.R.I.C., V.M.H., F.R.S.

Jesse Amos was by early training a botanist, but his later career as farm manager at East Malling inevitably widened his interests to include every aspect of fruit production, from the propagation of young plants in the nursery to the marketing of the various fruit crops. That he was closely concerned with the early manurial experiments at the Station is evidenced by the presence of his name on the early reports of this work : that he was also deeply interested in the nutritional problems of his beloved fruit plants I can readily vouch for from personal experience, for it was my privilege on my frequent visits to East Malling to discuss many aspects of these problems with him. I have a suspicion, however, that he was somewhat disappointed that dung and organics, particularly meat and bone, were not eventually found to provide the cure for all nutritional ills.

When I was invited to give this lecture it thus seemed appropriate that I should recall some of the early views on the nutrition of fruit crops and trace the developments that have led to the present-day manurial and management practices.

The years immediately following the end of World War I may be taken as marking the beginning of the period of active progress in the solution of many of the outstanding nutritional problems of fruit crops, not only in this country but also in all the main fruit-growing areas of the world, including the U.S.A., Canada, European countries, South Africa, Australia, and New Zealand. From all these areas substantial contributions to knowledge have been made which together have virtually revolutionized orchard practices.

Pre-1920 period

Before summarizing the results of experimental work prior to 1920, it will be useful to refer briefly to cultural and manurial practices then in vogue, as these will serve to reflect the state of knowledge of these subjects at that time.

Fruit crops, with the exception of sweet cherries and fruit produced in the so-called farm orchards, mainly cider fruit and culinary apples, were then generally regarded as needing conditions of intensive arable cultivation, combined with liberal manuring, particularly with dung and organic manures containing organic nitrogen and phosphates. Potash manures were little used, as their effects were not readily perceived, and inorganic fertilizers were suspect as being too quick acting, and for this reason likely to promote sappy growth and diseased conditions.

In considering these practices and their likely effects, it must be appreciated that other ideas of commercial fruit production, in comparison with modern knowledge and practices, were correspondingly primitive—e.g., as regards varieties and standardized rootstocks, spraying equipment and spray materials, storage and marketing arrangements. Under the conditions then prevailing Cox was regarded as non-commercial, as most orchard trees of the variety were unhealthy and cropped unsatisfactorily, conditions which were later remedied by the use of standardized rootstocks, combined with suitable manuring and spraying treatments.

Nutritional experiments before 1920 had been confined to field manurial experiments, modelled on the classical experiments of Lawes and Gilbert at Rothamsted. The main series in Britain had been those of Bedford and Pickering at Woburn, and of Dyer and Shrivell at Hadlow in Kent.

The Woburn experiments were carried out over a period of twenty-two years on apples, bush fruits, and strawberries, on two widely differing soil types—a heavy clay at Ridgmont and a light sandy soil, deficient in potash, at Milbrook. On the clay soil the results obtained appeared somewhat

* The eighth Amos Memorial Lecture, delivered at East Malling Research Station on 24th November, 1955.

puzzling. Thus, on apple trees, annual dressings of dung at 30 and 10 tons per acre or of ' complete artificials ', equivalent in plant food content to these two amounts of dung, produced no significant effects on either the growth or fruiting of the trees, whereas large increases were obtained from similar treatments on bush fruits, nursery stock, and vegetable crops. The ploughing in of green crops also produced bad effects on the apple trees. Pickering accepted these results as perhaps natural for a fairly fertile soil.

On the sandy soil, large increases in growth and cropping were obtained from the manurial treatments on all fruits except strawberries, on which the only significant effect was the increased longevity of the plants receiving dung. On this soil the beneficial effect of potash on apples was demonstrated, as is shown by the following comparative cropping figures :

	No Manure	Complete Artificials	Omit Potash	Omit Phosphate	Omit Nitrogen
Relative yields ..	72	100	67	117	103

At Woburn, Pickering also carried out extensive experiments on the effect of a grass cover on the growth of fruit trees, and concluded that grass roots exuded a substance toxic to the tree roots.

The Woburn results were widely discussed by leading fruitgrowers of the period, who were generally great believers in heavy manuring for their crops. The results, although not generally accepted as likely to be widely applicable to commercial plantations, did raise doubts in the minds of many leading growers as to whether their practices were sound, and promoted a critical outlook towards orchard practices in general.

The Hadlow experiments had limited objectives—to determine how far ' artificial fertilizers ' could supplement or wholly replace dung in the manurial programme. The experiments were carried out on apples, plums, gooseberries, currants, and strawberries over a number of cropping seasons, the soil used being a poor clay loam. In these trials manures generally increased crops, except strawberries, and outstanding effects of dung and of potash, where dung was not given, were evident.

In the U.S.A. extensive experiments on apples and strawberries had been carried out at several state experimental centres with very conflicting results. The lack of consistent and helpful results was commented on in two papers read before the American Society of Horticultural Science by W. H. Alderman and R. D. Anthony respectively in 1919. These workers in particular pointed to the meagre results obtained from the vast expenditure and labour entailed in manurial experiments on orchard trees.

In addition to the formal field experiments various pathological conditions of fruit plants, under the terms chlorosis, mottle leaf, rosetting, die-back, etc., and believed to be related to faulty nutrition, had been investigated, but little progress had been made with any of the problems.

The points that had emerged from the field experiments up to 1920 may be summarized as follows :

(1) In the U.S.A., quick-acting nitrogenous manures, such as nitrate of soda and sulphate of ammonia, had generally produced marked increases in tree growth and cropping where trees were in poor condition in grass orchards.

(2) In England, large increases had generally been obtained on bush fruits from the use of dung and smaller increases from artificial fertilizers. Results on strawberries had been inconclusive, though dung appeared to increase the longevity of the plants.

(3) The action of phosphate and potassic manures in orchards was very variable. In England, potash had been clearly beneficial at two centres on poor soils ; no beneficial effects had followed from the use of phosphates. In the U.S.A., potash had generally been without effect, and phosphates had only produced good results indirectly by improving the growth of cover crops.

(4) Nitrogen was the only element that had been shown definitely to affect the character of the fruits.

(5) There were plantations of trees in which ordinary systems of manuring did not produce measurable effects either on tree growth or fruit production.

Pot experiments

It was against this background of meagre achievements from field experiments that a programme of work on fruit tree nutrition was considered at Long Ashton in 1920. It was then concluded that little progress was likely to follow by merely continuing this kind of investigation and that something more fundamental was needed.

It was finally decided to attempt to study the specific effects of the main nutrient elements on various fruit crops in sand culture. At that time much work had been done on agricultural crops in

solution cultures, following the pioneer work of Sachs and Knop dating from the 1860's, but we could find no record of its use in the literature for tree crops. Nor did we feel that this method would be suitable for fruit plants, owing to their large size if growth was to be successful, to the difficulties of aerating nutrient solutions, and to the desirability of growing the plants over a number of seasons to obtain fruiting records. Sand cultures seemed a more promising alternative, but here again there was no precedent. Could trees really be grown successfully in sand, fed solely with inorganic nutrients? This point had to be determined.

It is interesting to note that almost simultaneously this same question was being asked by Reed and Haas, who were working on *Citrus* crops at Riverside, California. Like ourselves these workers decided to use sand cultures and their results closely paralleled our own.

The Long Ashton pot experiments, the first series was on apples, were begun in the spring of 1921, and they yielded significant results even in the first season. In the second season they were extended to black currants, gooseberries, raspberries, and strawberries. In the earliest stages the records consisted of the visual effects of deficiencies of the major nutrient elements and of quantitative data relating to vegetative growth, blossoming, and fruiting. Differential effects due to varieties and rootstocks were also noted.

Two interesting results relating to ratios of nutrient elements emerged from the first two seasons' experiments : those of nitrogen/potassium and potassium/magnesium ratios that have since proved to be of great importance in the orchard.

The second step was to examine the effects of the various deficiencies on the content of mineral nutrients in the various parts of the plants—in leaves, bark, and wood of shoots and stems, and in fruits. The finding from these investigations that deficiencies were reflected in these different parts of the plants, and particularly in the leaves of terminal shoots, led us to test this method later for diagnostic purposes in the field. An essential point in the development of this leaf analysis method was the examination of the seasonal cycles of the various nutrients in the leaves ; this work was carried out on the apple.

Field investigations

Armed with the data from the pot experiments the next step was to attempt to apply the new knowledge in the field. This was done in two ways : by the laying down at Long Ashton of fertilizer plots on various crops to study deficiency treatments and by examining unsatisfactory crops in commercial plantations. The results on the Station plots have been described in a number of papers in the *Journal of Pomology* (now the *Journal of Horticultural Science*), and amply confirm the effects noted in the pot experiments in regard to growth effects and chemical features. The early investigations in commercial plantations stressed the prevalence of leaf scorch and the importance of lime induced chlorosis (iron deficiency) on calcareous soils, and showed that the practical problem of grass effect was essentially that of nitrogen deficiency.

At an early stage of this work we joined forces with Hatton and his colleagues who had been studying our results, particularly potash deficiency effects in relation to the behaviour of the apple rootstocks, and it was soon possible to place the rootstocks and also some varieties—in order of susceptibility to potash deficiency.

The initial field investigations, which had been in the nature of nutritional surveys, were followed by the establishment of manurial trials at a number of widely scattered centres on different crops, and, in particular, prolonged investigations on leaf scorch and chlorosis, involving field and chemical data, were undertaken and carried through to the points when practical solutions to these important problems could be recommended.

Two interesting points were investigated during the course of this early work, the possibility of supplying the nutrients by sprays through the leaves—an operation which is now common commercial practice and the phenomenon of nutrient leaching from the leaves, which was first shown to be of serious consequence, particularly on Cox's Orange Pippin, in the unusually wet season of 1924.

Soil and pomological surveys

The early field investigations received a great stimulus from the establishment of the so-called Fruit Soils Surveys, which originated from a discussion in the Advisory Chemists' Conference in 1922 on soil and crop relationships.

The outcome of the discussion, which had been initiated by the late Mr. A. B. Bruce of the Ministry of Agriculture, was the establishment of a committee to organize and supervise survey work to examine the relationships between soil conditions and the growth of fruit crops. The first surveys were carried out in Old Red Sandstone fruit districts of the West Midlands and the Wisbech area, by

Long Ashton and the Horticultural Department of Cambridge University respectively. Some very striking relationships were established in this early work, which was later extended to other important fruit-growing areas, including West Cambridgeshire, the Vale of Evesham, and the Lower Greensand and Wealden areas in Kent and Sussex.

The results of these surveys have provided a sound basis for the extension of fruit planting in the various areas examined and have also enabled some broad generalizations to be made regarding the relationships between soil conditions and the successful growth of fruit crops.

The main relationships established are as follows :—

(1) The growth of all fruit crops is generally satisfactory on deep, well-drained soils, particularly on soils of loamy texture.

(2) On some soils of this nature growth may be over-vigorous, particularly on the heavier loams when water conditions in the soils are particularly favourable.

(3) The different classes and varieties of tree fruits react differently to soil texture. Cherries prefer light soils, and may fail on clay soils on which other tree fruits are successful ; plums, by contrast, prefer heavy soils and often fail on soils of sandy texture. In any soil series the lighter textured soils will often be more suitable for dessert varieties of apples and the heavier types for the culinary sorts.

(4) Soil conditions that were found to be unfavourable for the healthy growth of fruit crops, in the absence of special ameliorative treatments, were as follows :

(a) *Light textured soils.*—Poor acid sands and gravels with unfavourable water supplies and deficient in the basic nutrients, potassium, magnesium, and calcium. They give particularly poor results where their subsoils are compacted or contain well developed iron pans and where rock or clay deposits occur at a shallow depth.

These soils, in addition to their poor nutrient status, are liable to dry out excessively in summer and may also be subject to seasonal waterlogging where the subsoils contain impervious layers.

(b) *Shallow, medium-textured, or heavy soils.*—The characteristic of these soils is their impervious subsoils, which may be the result of poor weathering or erosion of the surface layers.

They are poor in organic matter and mineral nutrients, and are subject to wide fluctuations in water content, waterlogging readily in wet periods and drying out rapidly during droughts.

(c) *Soils with impeded drainage.*—These include heavy soils on poor sites where drainage is slow, and soils with high water tables, which may be due to a high regional water table (as on low-lying alluvial flats) and to the presence of underlying impervious rocks.

(d) *Highly calcareous soils.*—These include soils on the chalk and limestone formations, soils containing calcium carbonate layers and calcareous gravel in the subsoil, and soils in which lime is distributed more or less throughout the soil profile, as in soils derived from shell sands and calcareous clays. Deficiencies of iron and manganese are common on these soils and the former may preclude their use for fruit growing.

The mineral requirements of fruit crops

During the present century much attention has been given by plant physiologists and chemists to the problem of the essentiality of mineral elements for plant growth. The early interest derived from the water culture experiments of Sachs and Knop, and a great stimulus was later given by the findings of Bertrand, Javillier, Mazé, and Aghulon regarding the essential nature for plant growth of the trace elements, manganese, zinc, and boron. During the period 1920–1940 clear proof was forthcoming, not only of the essential nature of these latter elements for many plants, as shown in academic studies, but also for field crops, and copper and molybdenum were also added to the list of essential trace elements. Even more recently, chlorine, so commonly used in agriculture, has been proved to be essential for the growth of tomato and must now be considered in this respect in relation to other crops.

It is of interest to see how far the individual essential elements and some others have been shown to be of importance in practical fruit growing. Before doing this, however, it may be helpful to digress a little to consider the list of elements now regarded as essential for plant growth, and to discuss the classification of mineral elements that occur in plants and comprise their so-called mineral status.

Many mineral elements have been found in the ash fraction of plants, and as the result of experiments and experience these have been classified as follows : (a) *essential elements*—comprising *major* elements needed in relatively large amounts by plants —nitrogen, phosphorus, calcium, magnesium, potassium, and sulphur ; *minor* or *trace* elements needed only in relatively small amounts –iron, manganese, boron, copper, zinc, and molybdenum (chlorine is temporarily assigned to this group, though actually it falls between the major and minor groups in the quantitative classification adopted) ; (b) *beneficial elements*—these are elements which produce beneficial effects on certain plants, but have not been proved to be essential to complete the growth cycles of the plants. Sodium is an outstanding

example of this group ; (c) *other elements*—these are elements for which no good effects on growth have been shown and they may even be harmful to the plants in which they occur.

The mineral status refers to the amounts and interactions of the elements of these three groups in the plant tissues in relation to their effects on the metabolic processes.

We may now pass on to the discussion of the role of these elements in the nutrition of fruit plants and of the nature of the problems associated with them in the orchard.

(a) The essential elements

In the first place it can be stated that all the essential elements, with the exception of chlorine, have been shown to be essential for fruit plants. So far no critical experiments have been made with chlorine and the question in any case is likely to be of academic interest only in view of the universal occurrence of the element in chloride form, and the widespread use of manures and fertilizers containing chlorides.

Moreover, eleven of the twelve elements for which proof of essentiality for fruit plants is available have been shown to be of importance in orchards, deficiencies of them resulting in poor growth and low fruit yields, and often in so-called physiological diseases. The exception is sulphur, which possibly is always adequate because of the large amounts applied almost universally to fruit, both in fertilizers (as sulphates) and in spray materials.

A point of special interest is that, apart from the elements commonly used in fertilizers,—i.e., N, P, and K—the importance of the other essential elements has generally been established as the result of special investigations of serious diseased conditions that have occurred in orchards.

The following points may be made in respect of the individual elements.

Nitrogen.—The importance of this element and its effects on growth, fruitfulness, and fruit quality are too well known to you to discuss here.

Phosphorus.—Whilst sand culture experiments with many fruits have shown the serious effects of a deficiency of this element on growth, fruiting, and fruit quality, deficiency effects reported in field crops have been rare and there seems no justification for the application of large dressings of phosphates to fruit crops, though deficiency effects must be guarded against in view of their serious nature. The effect of phosphates in promoting high quality in *Citrus* fruits is of special interest. Excess of phosphorus has been shown to promote deficiencies of iron and zinc.

Calcium.—Calcium deficiency of fruit plants, as is general for higher plants, results in shoot die-back and defective roots. In orchards, the effects of calcium—deficiency and excess—are complicated by pH effects. Experience has shown that many fruit crops can grow well on soils of low calcium status—pH as low as 5·0—though high calcium plants, such as the blackcurrant and *Citrus* species, may be notable exceptions. On the other hand, on high calcium soils deficiencies of trace elements, particularly of iron and manganese, are prevalent in fruit crops (possibly a pH effect) and potassium deficiency is common (probably mainly a high calcium effect). To summarize, it may be stated that calcium status is likely to be satisfactory for fruit crops when soil pH is between 5·5 and 6·5.

Magnesium.—This element has proved to be of considerable importance for many fruit crops, much more so than for agricultural crops, and the application of magnesium-containing sprays and fertilizers is now a common practice in many apple and *Citrus* orchards.

In magnesium deficiency problems the relationships of magnesium to nitrogen and potassium have been shown to be of outstanding importance. Magnesium deficiency has possibly been the most common deficiency in English orchards during the past decade.

Potassium.—Potassium has proved to be critical for the satisfactory nutrition of fruit crops in Britain. It is probably true to say that before it was shown that leaf scorch was due to potassium deficiency, many soils had been discarded as unsuitable for fruitgrowing because of this malady. Moreover, it is an undoubted fact that the use of potash fertilizers has played a dominant role in the successful utilization of many soils for fruitgrowing in this country since 1920. A point that has become abundantly clear in studying the potash needs of fruit crops on soils of widely differing fertility, is that the requirements of agricultural crops for potash on these provide little guidance as to the needs of fruit crops, and even on the most highly rated agricultural soils fruit crops may fail badly if not given liberal dressings of potassic fertilizers. In some recent fertilizer experiments on strawberries and bush fruits, notably at Long Ashton and the Rosewarne Experimental Horticulture Station, Cornwall, it has been shown that these fruits fail when given potash deficiency treatments, whereas agricultural crops and vegetables fail where phosphorus is omitted from the manures, thus again emphasizing the importance of potassium for the fruit crops and their low requirements for phosphorus.

There must now be very few fruitgrowers in Britain who do not recognize the great importance of potash manuring for their crops, and indeed the most important problem at present is possibly due to the over-application of this knowledge, bringing in its trail the problem of magnesium deficiency.

Sulphur.—Supplies of this element, for the reasons previously mentioned, have not so far been shown to be limiting in orchards.

Iron.—Deficiency of this element is of world-wide importance in fruit nutrition on calcareous soils, where the special pathological condition of the plants is known as lime-induced chlorosis. This condition has hitherto proved most difficult to remedy, as essentially it has been a problem of the low availability of iron in the soil and has not been amenable to the usual remedial measures of soil dressings and foliage sprays, though grass covers and stem injection treatments have afforded some degree of control.

Recent experiments have indicated that some of the new organic chelated compounds of iron may provide satisfactory means of control, though at present the costs are high.

Whilst iron deficiency is usually a problem of calcareous soils and may seriously limit the use of such soils for fruit growing purposes, the deficiency does occur on some acid soils, particularly in *Citrus* in Florida. Under these conditions its control is fairly readily effected by soil dressings of iron chelates.

Manganese.—This deficiency, like that of iron, is widespread in fruit trees of various kinds, on calcareous soils, in most fruit-growing areas of the world. Its importance in fruit crops in Britain was first recognized in 1943 when it was shown by Duggan to be the cause of serious failures of sweet cherry trees in Kentish orchards.

Since that time the deficiency has been recorded on most of the other fruits, gooseberries perhaps excepted. Raspberries, like sweet cherries, are particularly liable to the deficiency. In many orchards where the deficiency occurs the effects are not serious and, in any case, control can usually be simply and cheaply obtained by sprays.

Boron.—Diseased conditions of fruit trees now known to be caused by boron deficiency had been the subject of many intensive and prolonged researches, especially on apples, before the role of boron in these was ascertained. Typical of these researches were those carried out on the conditions of apple fruits known as Cork and Drought Spot by Mix and others in the U.S.A. and by Rigg and Tiller in New Zealand.

These problems were finally solved simultaneously in 1936 by McClarty and his colleagues in Canada and by Askew and his co-workers in New Zealand. Since the publication of the results of these workers the deficiency has been reported in many fruits, including apples, pears, *Citrus*, vines, stone fruits, and raspberries, from many countries of the world, but curiously enough the deficiency has not so far been proved to occur in fruits in our English orchards, even though the deficiency has been prevalent in crops such as sugar beet on soils commonly used for apple growing.

D. Mulder in Holland has suggested that Bitter Pit in apples is caused by a deficiency of boron in the fruit at a critical period of growth, but this view requires confirmation.

At Long Ashton we have examined several conditions of apple fruits, showing symptoms similar to those of boron deficient fruits, viz., corky flesh, pitting (including Bitter Pit), and severe skin cracking (similar to Drought Spot), but we have not been able to relate these to low boron status of the trees and fruits, and we have not been able to correct the conditions by boron treatments applied to the soil or as stem injections or foliage sprays.

Copper.—Serious pathological conditions of a number of tree fruits now known to be due to copper deficiency, e.g., exanthema of pears, gumming of stone fruits and *Citrus*, and summer die-back of apples, were well known in orchards in the U.S.A. and South Africa before their relationship to copper status was established by Oserkowsky and Anderssen. In Britain, summer die-back symptoms on apples were first observed on plots of the National Fruit Trials at Wisley about 1939, but the condition was not fully investigated and identified as due to copper deficiency until 1950, when both apples and pears had become seriously affected. Since that time the deficiency has been shown to occur at some other centres in pears, apples, plums, and cherries. At all centres pears have been noted to be particularly susceptible.

Zinc.—Like boron and copper deficiencies, the pathological conditions that result from zinc deficiency in tree fruits, particularly *Citrus* and apples, were well known and had formed the subject of many investigations long before proof of their connexion with zinc deficiency was established.

The first proof of zinc deficiency in fruit trees was obtained by Hoagland, Chandler, and Hibbard in 1931 in their investigations on Little Leaf or Rosette of apples in California. Their findings led to similar investigations on the old intractable problems of Mottle Leaf of *Citrus*, Pecan Rosette and, Bronzing of Tung, which were also shown by U.S. workers during the period 1932–36 to result from zinc deficiency. Mottle Leaf, in particular, is a serious problem in *Citrus* culture in many areas of the world, and, according to Chandler, zinc is rated as second in importance to nitrogen in the manuring of *Citrus* crops in California.

In England, proof of zinc deficiency in fruit trees was first obtained in 1949, again on an area of poor soil in the National Fruit Trials at Wisley, where both apples and pears were affected. Sub-

sequently the deficiency has been diagnosed in tree fruits at other centres in southern England. The deficiency has also been reported in deciduous fruit trees in other countries of Europe, notably in Holland and France.

Molybdenum.—A leaf spot condition of *Citrus* known as ' Yellow Spot ' was described by Floyd in Florida as early as 1908. The cause of this condition remained unknown until 1951 when Stewart and Leonard, following on the water culture experiments of Vanselow and Datta, showed by leaf analysis and spraying treatments on orange and grapefruit that the condition was caused by molybdenum deficiency. Severely affected trees recovered completely when a foliage spray containing 0·4 oz. of sodium or ammonium molybdate per 10 gallons was applied. So far the deficiency has not been reported in other fruit crops in the field.

Chlorine.—Although no instances of chlorine (as chloride) deficiency of fruit are on record, excess chloride injury has been frequently recorded, particularly in red currants, and differences in suceptibility of a number of fruits have been investigated. The investigations have shown that susceptible crops, e.g., red currants, gooseberries, and strawberries, tend to take up large quantities of applied chloride whilst the less susceptible fruits, e.g., apples and blackcurrants, absorb much less quantities under comparable conditions.

It should be noted that the heavy metal trace elements, manganese, copper, and zinc, when present in soils in excess, have all been shown to induce a deficiency of iron. As for many other crops the favourable range of boron in fruit plants is fairly narrow. Excess effects of this element have been commonly observed in California to arise from the use of irrigation waters containing small amounts of boron compounds. The usual symptoms of excess are marginal scorching of the older leaves of the trees.

(b) Beneficial elements

No element other than those in the essential element group has been shown to improve the vegetative growth or fruiting of fruit plants. In sand culture experiments at Long Ashton, the addition of relatively large amounts of sodium, in the form of sodium sulphate, to the complete nutrient solution produced no apparent effects on the fruit plants under test—apples, black currants, gooseberries, and strawberries.

(c) Other elements

No problems concerning these elements have been reported, though it has been shown that the Brazil nut has a high content of barium and it may well be that other fruits show similar selective properties for specific elements.

Nutrition and quality relationships in fruit

The effects of mineral elements on the quality of fruits are difficult to determine, as so many other factors of the natural environment and of management, and also the inherent properties of the plants themselves, may exercise large effects and mask the effects of the nutrient elements. Attempts to separate the effects of these numerous factors have been made in a long series of investigations at Long Ashton, mainly on apples grown under widely differing conditions of climate and management, but also on other fruits obtained chiefly from special manurial plots on the Station farm. Similar experiments on *Citrus* fruits have been carried out in the U.S.A., South Africa, and Palestine.

Most of our experiments on apples have concerned the effects of nitrogen and potassium, used separately and in combination, and have covered a range of levels from deficiency to excess amounts. With strawberries and black currants the effects of dung and phosphorus have also been included.

On apples the main effects have been as follows : —

Nitrogen.—High nitrogen fruits tend to be large and green when other elements are also present in adequate quantities ; keeping quality may be poor, due to attacks of rots or to the onset of physiological breakdowns ; nitrogen content of the fruit is high, acidity is not unduly affected, but sugars tend to be low. At medium levels of nitrogen, sugars tend to show peak values and then to fall as deficiency levels of the element are approached. The starved fruits are ' woody ' in texture and lack flavour.

Potassium.—The effect of potassium level on fruit quality varies with nitrogen level. At high values of the latter the fruits are of the large, high nitrogen type, tending to be green, of coarse texture and acid flavour. When nitrogen level is low the fruits are often highly coloured, sweet, and of high dessert quality. Potassium deficient fruits are notably small, ' woody ', and sub-acid, and may be sweet to taste. The effect of potassium on keeping quality is somewhat complicated. When the fruits are large (high potassium), keeping properties both as regards rots and breakdowns may be poor : small, potassium-deficient fruits may show fairly normal keeping qualities, but they may break down prematurely in low temperature stores.

Phosphorus.—Experience with fruits of different phosphorus status has been limited to crops from sand culture trees, and here the evidence has pointed to high acid content and poor keeping quality of phosphorus deficient fruits.

Magnesium.—Fruits from acutely deficient trees are small and of immature appearance, and are woody and flavourless to taste. Chemical data are not available.

Iron.—Fruits from iron-deficient, chlorotic trees may be highly flushed and the ground colour of the skin may be almost white ; sugar content tends to be low.

Manganese.—Observations have been restricted to commercial samples where the fruits have not shown any obviously abnormal features.

Boron.—Fruits from deficient trees are mostly valueless due to distorted shapes, skin cracks and russeting, and internal pitting and browning of the fleshy tissues, particularly in the core region.

Zinc.—Deficient fruits remain dwarfed and useless.

Calcium, copper, and molybdenum.—No data are available on the fruit characters in relation to the status of these elements. In cases of acute copper deficiency trees may fail entirely to bear fruits.

Experiments with strawberries from fertilizer experiments at Long Ashton have generally confirmed the results obtained for apples in relation to the effects of nitrogen and potassium levels, and have also shown how quality may be affected by dung and by organic and inorganic forms of nitrogen.

Results with *Citrus* fruits in California, South Africa, and Israel have shown consistent effects for nitrogen, phosphorus, and potassium, viz., large, coarse fruits of high acidity, where nitrogen and potassium are high, and the tendency for high phosphorus to give smaller and smoother fruits with thinner rinds, and with higher contents of juice and sugars and decreased acidity. Where potassium reaches deficiency levels the fruits are notably dwarfed. The similarity of the effects produced by the three elements on the quality of apples and *Citrus* fruits will be obvious.

Conclusion

In concluding this lecture, in which I have attempted briefly to outline the progress made in the main lines of research on the nutrition of fruit crops from 1920 to the present time, it will be useful to summarize the present state of knowledge and to indicate fields of study that could be profitably explored in the immediate future.

It will have been clear that we now know the main effects produced on fruit plants by deficiencies and excesses of the individual mineral nutrient elements, and that we can recognize these effects in the field and are able to apply practical treatments to modify or overcome undesirable effects. In addition, the special requirements for the various nutrient elements of different classes of fruit, and of varieties and rootstocks, are well known to skilled growers, and the various crops are, in general, given suitable manurial treatments to ensure healthy growth and cropping.

There are, however, some problems that still call for much more research. Among these I should place in the forefront the integration of cultural systems with manurial treatments, particularly for tree fruits, as I am convinced that our present manurial systems are wasteful and could be considerably modified and dressings reduced with beneficial effects on the nutrition of the trees. Of the possible cultural systems I should give the highest priority to the study of permanent grass and legume swards, and of systems utilizing surface mulches. The studies on swards should include the effects of the swards and their components on soil structure, soil moisture, and the mobilization and utilization of mineral nutrients.

Again, our knowledge of the relationships between vegetative growth and yields on the one hand, and the nutrient status of fruit plants, on the other, is still meagre. Studies of this subject can be expected to provide considerable information on the effects of fertilizer treatments and management practices on growth and cropping problems and lead to economies in, and the use of more efficient, manures.

There is also still much scope for study of the methods of applying nutrients to fruit trees. Foliage sprays, where effective, are much more economical than soil dressings, and by their more rapid action may give the grower more flexibility in controlling growth, fruiting, and fruit quality.

Lastly, much more work is needed on the relationships of nutrient status and the quality of fruits. This is a difficult and expensive subject to investigate and progress may be expected to be slow. But quality will become even more important in future and progress in this field, with its ultimate objective of still better fruit, should benefit alike the grower and the consumer.

POMOLOGY

A COMPARISON OF BLACK CURRANT CUTTINGS FROM STOOLED PLANTS AND FRUITING BUSHES

By R. J. GARNER, E. S. J. HATCHER,* and R. W. KEMP†

At a meeting of N.A.A.S. officers in November, 1950, the inspection procedure for black currant bushes was considered in relation to the nature of the material and its suitability for cuttings. It was felt that the stool-bed system could materially simplify the certification process, provided the hard pruning involved did not adversely affect the quality of the shoots for cuttings, nor induce abnormal growth which would hinder the recognition of Reversion. East Malling Research Station was asked to consider an experimental investigation of this problem.

Following discussion, it was agreed that a comparison of the performance of cuttings from existing sources was first necessary. In June, 1951, Dr. R. V. Harris and two of the authors (R.J.G. and R.W.K.) visited nurseries and farms in Norfolk to examine possible sources of cuttings and to consult growers and propagators. The stool system appeared very satisfactory, though stools had not been kept longer than ten years or so, indicating that long retention may be inadvisable. In this area no serious difficulties in rogueing for Reversion had been met, and no reversion-like symptoms were encountered in the shoots from stools or bushes used subsequently in the experiments. Opinions differed, however, on the suitability for cuttings of shoots from young and from older stools. The only general objection to the stool system arose from the fluctuation in demand for cuttings and this had been countered, to some extent, by alternating the treatment of rows, which were either cut down or left for fruiting according to need.

Source and nature of cuttings

The search in Norfolk for suitable comparable experimental material revealed no satisfactory source more than four years old. Material of this age was available from stools and fruiting bushes which had been planted 2 feet apart in alternate rows spaced at 4 feet. Two varieties were selected for trial, Wellington XXX, a very vigorous variety, and Mendip Cross, a variety of more moderate growth.

Shoots for cuttings were collected in the autumn of 1951, and again one year later, in the following manner.

Adjacent rows of stools and fruiting bushes, clear of headlands and shade trees, were selected. All shoots, 18 inches or more in length, were cut off at their base until 500 had been collected, the stools yielding many more shoots per yard of row than the fruiting bushes (Table I).

TABLE I

NUMBER OF SHOOTS 18 INCHES OR OVER HARVESTED FROM TEN YARDS OF ROW

Year	Wellington XXX		Mendip Cross	
	Stools	Bushes	Stools	Bushes
1951	185	10	143	35
1952	278	12	200	23

The shoots were graded according to length and this showed that there was a tendency for those from stools to be longer than those from bushes. The shoots from each of the four sources of variety and culture were divided into two classes, those from 50 to 70 centimetres length and those from 70 to 90 centimetres. Two contiguous cuttings, each 8 inches long, were made from the base of the shorter shoots and three from the longer ; the middle cuttings from the latter were not included in the experimental planting. Counts on random samples showed that cuttings from shoots taken from bushes had about 20 per cent more buds than those from stools, their mean internode length being correspondingly shorter.

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† National Agricultural Advisory Service.

Nursery treatment

The cuttings were planted in the open, on 28th November, 1951, in a soil of the Barming Series and, on 13th December, 1952, in a soil of the closely allied Langley Series, both medium or sandy loams within the Ragstone area. The experimental lay-out was the same in both years; six randomized blocks, each containing units of 10 cuttings of all sixteen types. Guard cuttings were placed at the ends of all experimental rows, and external guard rows were planted.

Cuttings were set vertically, with a single bud showing above ground, and were spaced 6 inches apart in the rows and 30 inches between rows. After one year all growth was cut back, and the cuttings were left a second season. Normal cultivations and sprays were given throughout.

Results

The percentages of cuttings which rooted are shown in Table II, the mean value for the 1951 planting being 78·2, and for the 1952 planting only 59·4. Wellington XXX gave a significantly higher 'take' than Mendip Cross in both years (74·3 over the two years compared with 63·2) and stool cuttings were superior to bush cuttings. Indeed, it was the extremely poor rooting of the Mendip Cross bush cuttings in 1952 which largely contributed to the overall seasonal and varietal

TABLE II

PERCENTAGE ROOTING OF CUTTINGS

	Wellington XXX				Mendip Cross				Mean
	Stool		Bush		Stool		Bush		
	1951	1952	1951	1952	1951	1952	1951	1952	
Short Shoot :									
Upper	85	58	80	48	78	67	47	23	60·7
Lower	88	65	85	62	78	82	90	30	72·5
Long Shoot :									
Upper	90	78	60	63	73	72	62	33	66·4
Lower	85	88	87	67	85	67	78	47	75·5
Mean	87·0	72·2	78·0	60·0	78·5	72·0	69·2	33·2	

TABLE III

SHOOT GROWTH PER ROOTED CUTTING (CM.)

		Wellington XXX				Mendip Cross				Mean
		Stool		Bush		Stool		Bush		
		1951	1952	1951	1952	1951	1952	1951	1952	
Maidens	*Short Shoot :*									
	Upper	39	59	38	63	32	62	36	39	46·0
	Lower	39	60	37	54	25	57	28	36	42·0
	Long Shoot :									
	Upper	39	76	40	60	37	62	32	50	49·5
	Lower	41	70	37	55	26	48	29	42	43·5
	Mean	39·5	66·2	38·0	58·0	30·0	57·2	31·2	41·7	
Bushes	*Short Shoot :*									
	Upper	255	444	235	450	220	413	293	242	319
	Lower	244	418	249	408	204	422	197	240	298
2-year	*Long Shoot :*									
	Upper	262	443	261	406	233	305	210	395	314
	Lower	263	405	238	392	188	330	227	305	293
	Mean	256	427	246	414	211	367	232	295	

differences. In general long shoots were rather better than short shoots, the effect reaching significance only in the second experiment, and lower cuttings rooted better than upper cuttings, in this instance with significance in the first experiment.

Growth in the maiden year was far greater in the 1952 than in the 1951 experiment, a difference which persisted through the second year (Table III). Wellington XXX made significantly more growth than Mendip Cross in both experiments, but only in the second was there a cultural source effect, stool cuttings then being superior to bush cuttings. Cuttings from long and short shoots did not differ significantly in their growth, but upper cuttings showed small but definite advantage over lower cuttings.

Discussion

The parent stools and bushes were comparatively young at the time of the experiments and it may be argued that the deleterious effect of hard cutting in the case of the stools had not yet appeared. Nevertheless, it should be borne in mind that bushes may also deteriorate as a cutting source. Indeed, the observations made on the weaker growing variety Mendip Cross rather suggest such a tendency, for the crop of bush shoots used in the second experiment was somewhat inferior, and this was reflected in subsequent rooting. These experiments show that, at four and five years of age, stooled plants yield shoots for cuttings which compare favourably with those from bushes in regard both to stand and growth. Moreover, stools provide a large amount of material from a small area which is much easier to collect than that from bushes. Since no pseudo-reversion resulted from the hard pruning of the stooled plant, diagnosis of Reversion presented no difficulty. It is concluded that stool shoots are in no way inferior to bush shoots as a source of cuttings and, from the propagation angle, stooled plants might well be used for the provision of material for certification.

Summary

The performance of hardwood cuttings from stooled plants and fruiting bushes of equal age, of two varieties of black currants, is compared. The material from stools proved quite satisfactory for cuttings. It was easier to collect and rooted and grew equally well, or rather better, than material from fruiting bushes.

SOIL MOISTURE DEFICITS DEVELOPED UNDER LONG AND SHORT GRASS

By J. E. GOODE

Rogers, Raptopoulos and Greenham (1948) showed that an important part of orchard sward management is frequent mowing during the growing season. More recently, Greenham (1953) stated that frequent mowing has been found effective in preventing serious competition with the tree for moisture and nitrogen and that a suitable sward, frequently mown, is in most cases the best form of soil management for English orchards.

To a large extent these observations were made during field studies on the effect of differently managed swards on tree behaviour. More fundamental information is required for an improved understanding of the effect of management on sward behaviour, particularly on the competitive behaviour between sward and tree, and especially in respect of soil moisture utilization.

Trial plots

In October 1953, a study was begun of the soil moisture deficit development in a fine sandy loam soil under long and short grass using four 6 ft. square grass plots, which had been kept short since 1951. The plots were part of a randomized experiment in which temperature differences associated with various cultural methods had been observed. The grass cover consisted of a perennial ryegrass and wild white clover mixture, which had been sown at the commercial rates of 16 lb. and 2 lb. per acre respectively. There was a close cover of turf in which the clover content had been maintained. All plots were similar at this time.

It was appreciated at the outset that these plots, being small and relatively isolated, might disclose rather higher transpiration rates than would be expected from similar cover within extended areas. However, it was considered that this should in no way affect the primary purpose of the study, which was to determine the extent that frequent mowing restricted the amount of water which could be utilized from the soil by a grass sward.

Management

In October, the first cut was made on the two plots which were to be given the frequent mowing treatment, whilst the grass was left uncut on the other two plots. Adopting normal orchard sward management practice, no further cuts were made until the spring of 1954 and at the time of the first spring mowing, in mid-April, there was very little difference to be observed between the ' long ' and ' short ' grass plots.

From mid-April to the end of October the mown plots were cut 13 times, the mowing frequency being determined by the growth of the sward which was maintained at 2–4 in. until mid-August when no further cut was given until the last, in October. The mowing frequency is shown in Fig. 1. A Green's verge cutter was used which cut close and simulated a gangmower. Clippings were left on the surface.

The long grass was left uncut throughout the season. Growth was rapid, reaching 12 in. by the end of May and achieving a maximum height of 24 in. by mid-June when the grass flowered and subsequently began to lie. By late July a natural hay mulch layer had formed over the plots, but very quickly new grass growth penetrated the mulch and by the end of August the long grass plots carried a sparse green cover of ' mulched grass '. At this time, the rate of growth decreased considerably, and by the end of the season there was little difference in height between the two treatments although the short grass formed a much more compact cover than did the new growth on the long grass plots.

Soil moisture deficit

Soil samples for moisture content were obtained by means of a $\frac{7}{8}$ in. screw auger whilst the soil was moist, and with a 1 in. tubular auger when the soil was dry. Samples were extracted at 6 in. intervals to a depth of 3 ft. from two random positions on each plot at each sampling date. The number of samples which could be taken at any one time was limited by the size of the plots, but owing to the small area covered by the plots the soil was relatively uniform.

Moisture content was determined by oven drying at 105° C to constant weight and converted to inches of water using known volume weight values for the soil. The differences between the soil

moisture content at field capacity and the moisture content of the individual samples gave the soil moisture deficits.

Results.—Fig. 1 shows the total deficits in inches to a depth of 3 ft. under the two types of grass management at each sampling date. The total available reservoir of soil moisture in the 3 ft. depth of soil is also shown, to indicate to what extent the deficits approached exhaustion of the soil moisture reserves. Fig. 2 shows clearly in which soil zone the major difference between the deficits under the two managements occurred.

The deficits under both treatments were similar up to the beginning of May, when about 1·5 in. of the soil moisture reservoir had been used. This similarity is not surprising since the difference in management could not begin to express itself until after mid-April, when the first spring cut was made on the short grass plots. By the end of May, the deficit under the long grass, which was then

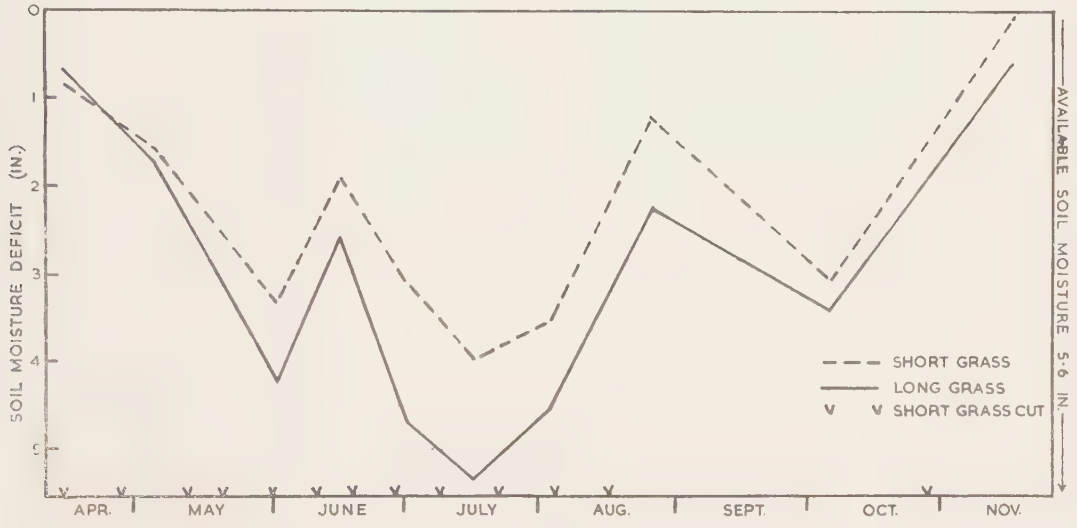

Fig 1.

Soil moisture deficits in 3ft. of soil under long and short grass.

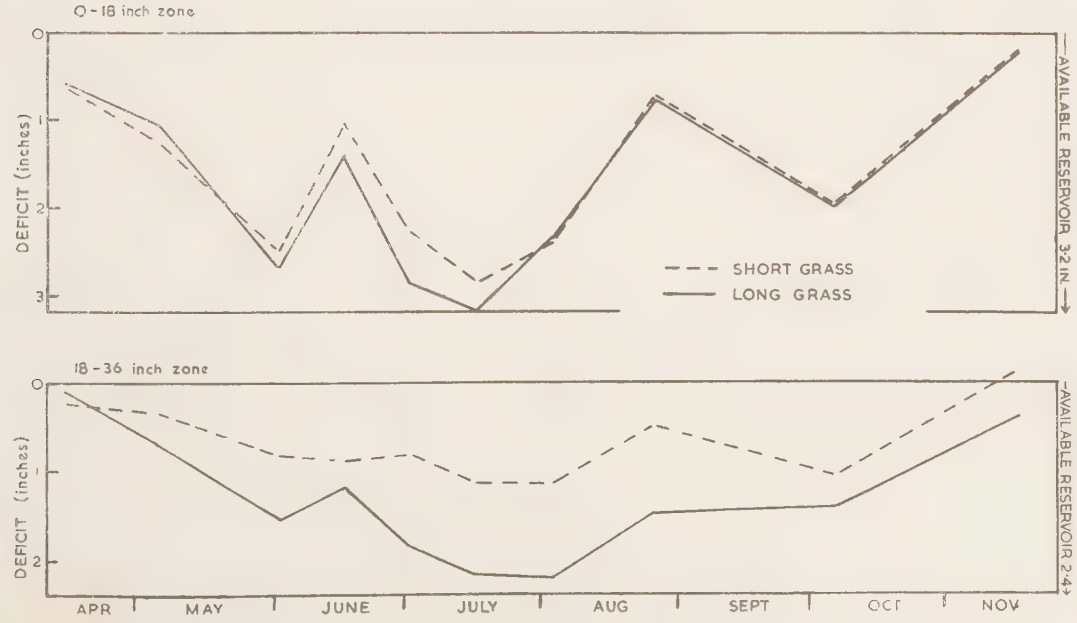

Fig 2.

Soil moisture deficits under long and short grass.

10–12 in. high, was 0·9 in. greater than that developed by the short grass, an amount sustained chiefly in the 18–36 in. soil zone, and this order of difference persisted in the 18–36 in. depth until the end of August.

The greatest total difference found during sampling was 1·6 in. which occurred at the end of June after the long grass had reached its maximum height and had flowered. By mid-July, the maximum deficits were 5·3 in. under the long grass and 4·0 in. under the short. At this time the long grass was already forming a hay mulch, having exhausted the available soil moisture reservoir within its root zone—practically the entire reservoir of the 3 ft. depth of soil. At the same time, the short grass, although having practically exhausted the available moisture reserves in the 0–18 in. soil depth, had utilized slightly less than half of the available reserves in the 18–36 in. zone.

The complete change-over from a fully transpiring cover to a moisture-conserving mulch layer, which occurred at this time on the long grass plots, is reflected in a decreasing deficit difference between the two treatments. This decrease in the difference between deficits was less than had been expected and this is attributable to two reasons. Firstly, when transpiration losses from the long grass became negligible, they were probably also reduced temporarily from the short grass, due to near exhaustion of the available reserves in mid-July, the time of maximum deficit. Secondly, the new growth of grass on the long grass plots appeared to utilize the soil moisture reserves at a rate similar to that of the grass maintained short, Fig. 2. Thus the deficits in the 0–18 in. soil zone, under both treatments, remained identical throughout the remainder of the season but the mulch of long grass, together with the high rainfall received in late July and through August, were insufficient to replenish the reservoir in the 18–36 in. zone to the level of that under the short grass, and even by mid-November a deficit persisted in the deep soil under the long grass.

This study suggests that frequent mowing reduced the rate of water usage by grass, as well as the total reservoir tapped. However, before such conclusions can be drawn it is necessary to consider the data further.

First, it seemed necessary to know whether the higher rate of water usage by the long grass was due to a higher rate of transpiration loss or whether transpiration rates of long and short grass were similar, but that transpiration losses were reduced from the short grass due to a check or succession of checks brought about by high soil moisture stress conditions in a smaller root zone.

Actual transpiration losses from the experimental plots were computed from the loss or gain in soil moisture, and from rainfall received, over each period between soil sampling. The values used in the computation are given in Table I.

TABLE I

ACTUAL AND POTENTIAL TRANSPIRATION LOSSES (INCHES OF WATER)

Period	Rainfall	Soil loss or gain		Transpiration loss for period		Total cumulative transpiration loss		Potential transpiration loss (Penman) +0·35
		Long	Short	Long	Short	Long	Short	
– 13 April	0·35	−0·67	−0·84	1·02	1·19	1·02	1·19	1·11
14 April – 4 May	0·78	−1·08	−0·76	1·86	1·54	2·88	2·73	2·57
5 May – 31 May	0·93	−2·47	−1·72	3·40	2·65	6·28	5·38	5·12
1 June – 15 June	2·34	+1·63	+1·41	0·71	0·93	6·99	6·31	6·62
16 June – 30 June	0·22	−2·10	−1·18	2·32	1·40	9·31	7·71	8·24
1 July – 15 July	0·45	−0·64	−0·88	1·09	1·33	10·40	9·04	9·64

The relationship between transpiration loss from the short and long grass, which is shown by the regression in Fig. 3 has been evaluated only up to the maximum deficit of 5·3 in. for the long grass, because after the development of this deficit the long grass plots ceased to function as fully transpiring units.

The data fit the regression line very well and there is no evidence of an early check to transpiration loss from the short grass, indicating that the greater rate of deficit increase under the long grass was due to a higher rate of transpiration as a result of the increased transpiring surface of the long grass under the conditions of free ventilation afforded by the small isolated plots. It is noteworthy that the ratio of long grass to short grass transpiration rates, given by the regression equation, is 10 : 8, and that 9 : 7 is the ratio of transpiration surface of the plots, assuming this to be the external surface area of the vegetation given by the dimensions 6 ft. square by 3 in. mean height for the short grass, and 6 ft. square by 9 in. mean height, excluding inflorescences, for the long grass.

Penman (1952) reported that Makkink in Holland found that long grass transpired more than short, which he states is almost certainly an aerodynamic phenomenon. Hence it is possible that a higher rate of loss of moisture may occur in extended areas of long grass than in similar areas of short grass. In the absence of the very free ventilation offered by small isolated plots however, the important difference between different managements of grass will more probably lie in the extent that they limit the amount of soil moisture that a sward can use, rather than the rate at which the soil moisture is used.

Fig. 1 shows that the maximum deficits were 5·3 in. under long grass and 4·0 in. under short, but unless it can be shown that the rate of transpiration loss from the short grass was checked at a

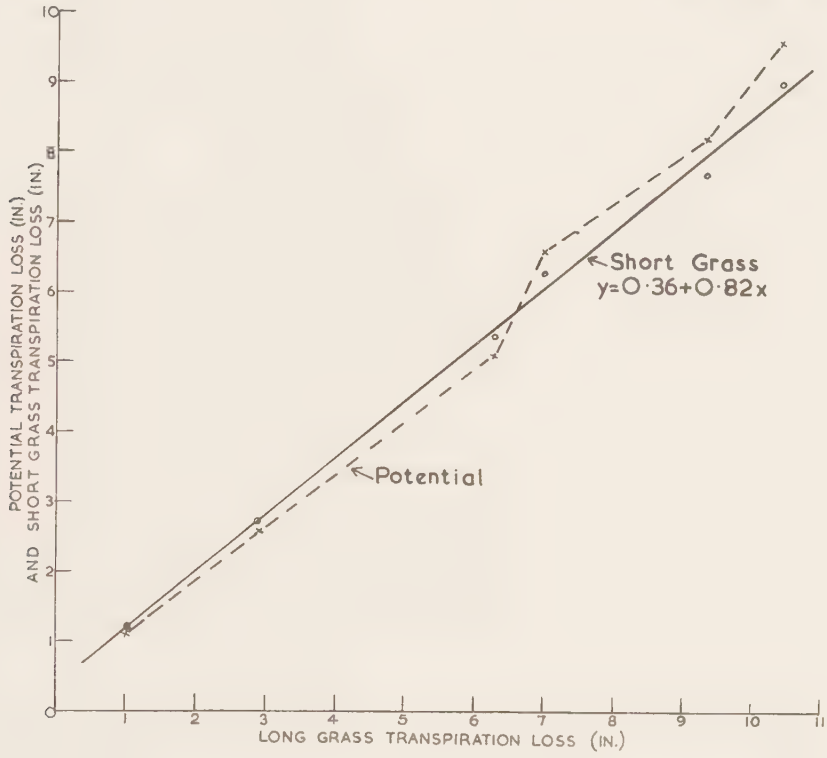

Fig 3.

Relationships between long and short grass transpiration losses and potential transpiration loss.

deficit value below the maximum developed under the long grass, it remains a possibility that had drying conditions persisted after mid-July, the short grass would have developed a maximum deficit similar to that under the long.

In order to determine whether a check occurred to transpiration loss from the long and short grass swards, use has been made of potential transpiration loss values calculated daily from climatic data during the summer season by the method of Penman (1949). It was not expected that the transpiration losses from the isolated grass plots would be similar to the potential transpiration loss values which strictly apply to extended areas of short green cover. However, the potential transpiration rate provided a convenient standard against which to compare the transpiration rates from the experimental plots. Cumulative potential transpiration losses over the sampling periods are given in Table I. These calculated losses are determined from the 1st April, and in order to bring them into line with the actual transpiration losses determined from soil moisture deficit and rainfall, 0·35 in. has been added to the first period, since this was approximately the deficit at the 1st April and is included in the soil loss values for this period.

Potential transpiration losses have been plotted against long grass transpiration losses in Fig. 3, and this shows a very close similarity between the potential transpiration rate and the short grass transpiration rate. The cross-over which occurs in the period 1st to 15th June, and again the divergence over the period 1st to 15th July, indicate that the transpiration losses from both the long and short grass suffered a check during these periods. The first check follows a deficit of 3·0–3·5 in. for

short grass and 4·0–4·5 in. for long, whilst the later check again follows the development of a deficit of 3·0–3·5 under the short grass, but of 4·5–5·0 in. under the long. These values, at which a check occurs to transpiration loss, agree with Penman's (1952) root constant for grass of 3–5 in. This constant is defined as the maximum soil moisture deficit that can be built up without checking transpiration.

Conclusions

Several conclusions can now be drawn which have an important bearing on grass management in orchards.

It is apparent from Fig. 2 that competition for soil moisture between grass and trees can be considerably reduced by maintaining swards short. Long grass, whether left uncut, or cut infrequently, will exploit a deeper soil zone than grass mown frequently and hence will compete to a greater extent with the deeper roots of fruit trees for the available moisture reserves.

Long grass may impose more prolonged or more intensive competition for soil moisture depending on the rate of transpiration compared with short grass, but in either case, it will be to the extent of competing for about one-third more water than short grass, since it has been shown that losses from short grass are checked at between 3·0 and 3·5 in. whilst the limiting deficit for long grass is from 4·0 to 5·0 in. These values probably have a wide application since they lie within the root constant range which has been fairly well established for grass.

Recent trials with apple trees at East Malling suggest that growth in particular, and fruit size to some extent, are reduced if replenishment of the soil moisture reserves does not occur soon after 50 per cent of the reserves has been used. This means that in many fruit soils with limited moisture reserves, the critical deficit will be 3–4 in. or less, and, if such soils are grassed down, it is of great importance economically to maintain the swards close cut. If, however, water reserves are not limited, or irrigation forms part of the orchard management, full advantage may be taken of the higher maintenance level of soil fertility to be derived from allowing the grass to grow more vigorously.

The grass species used in this study, S.23 perennial ryegrass, has a fairly vigorous rooting habit. The rooting depth of some of the weaker species is known to be shallower, and close cutting can reduce the maximum deficits developed by 0·5–1·5 in. below that of the close cut S.23 (Goode, 1956).

The comparison has been carried out on extremes of management, hence some commercial treatments of swards may be intermediate between the two studied. It should be pointed out, however, that infrequent cutting may give rise to even greater competition for soil moisture than no cutting at all, for the hay mulch stage is eliminated and with it, the consequent reduction in transpiration loss.

Summary

The soil moisture deficits developed under frequently mown and uncut swards of S.23 perennial ryegrass mixed with wild white clover have been measured and are discussed.

Long grass fully exploited the moisture reserves to a soil depth of 3 ft. whilst short grass fully exploited the 0–18 in. depth, but only partially utilized the reserves in the 18–36 in. depth. It has been shown that close and frequent mowing may conserve from 1·0 to 1·5 in. of water.

Thus the recommendation to mow frequently, in order to conserve water, is shown to be well founded.

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SOIL MOISTURE DEFICITS UNDER SWARDS OF DIFFERENT GRASS SPECIES IN AN ORCHARD

By J. E. GOODE

The harmful effects of vigorous swards as cover crops in fruit plantations have been described by Rogers, Raptopoulos and Greenham (1948). More recently, Greenham (1955) has referred to the effects of a number of different swards sown in 1951 on trees of Laxton's Fortune on M.II, planted five years prior to grassing down. He states that swards of S.50 timothy and natural swards consisting mainly of annual meadow grass (*Poa annua*), have offered less competition and have checked trees less, than S.23 perennial ryegrass, in the first three seasons after grassing down.

The differential checking of trees by strong and weak grass species has been considered to be mainly due to a greater utilization of soil moisture and nitrogen by the more vigorous grasses in the early years of sward establishment (Greenham, 1955 ; Rogers *et. al.*, 1948).

S.23 perennial ryegrass and S.50 timothy though unlike in habit are not strongly dissimilar in vigour, the S.23 being rather more vigorous than the S.50, but both species are considerably stronger in growth than annual meadow grass. This contrast in vigour and habit between the three species, together with their different effects on tree behaviour led to a study, in the summer season of 1954, of soil moisture under the three types of sward in the trial referred to by Greenham (1955). The purpose of the study was to determine to what extent utilization of soil moisture under the three swards differed and to assess how far this might account for the differential checking of the trees.

The estimation of the soil moisture deficit

Soil samples were taken from three plots of each type of sward for moisture content determination. Samples were extracted at 6 in. intervals to a depth of 3 ft. from two positions on each plot, one on the north and one on the south side of the experimental Laxton's Fortune trees mentioned above. Sampling positions were about four feet away from the base of the trees' trunks. Moisture content was determined by oven drying the soil at 105° C. and converted to inches of water content using known volume weight values for the soil. By difference from the moisture content at field capacity, the soil moisture deficits under the three types of sward were established. Determinations were made at approximately monthly intervals from mid-May to mid-October inclusive.

Results

Fig. 1 illustrates the soil moisture deficits in the top three feet of soil under each type of sward. Deficits were greater under the S.23 than under the other two grasses, the maximum deficit under the S.23 being 0·96 in. greater than that under the natural sward but only 0·26 in. greater than that under the S.50. Since there is no reason to believe that the water requirements of the trees in any of the swards differed appreciably, the much lower deficit under the natural sward must be a sward effect and could well account for the better tree growth associated with this sward than that with the S.23 sward. The difference between deficits under the S.23 and S.50 swards in 1954, however, appears to be inadequate to account for any appreciable difference in the growth of the trees in these two swards. But, the season in which the study was made was one of low soil moisture deficit and hence only small differences between the soil moisture deficits were built up under these two, more vigorous, swards. A difference, of importance in respect of tree growth, might have been observed between the deficits under the S.50 and S.23 swards if drying conditions had been pronounced and potential deficit development high as in 1952, the year after grassing down these plots.

In 1952, the annual meadow grass became scorched early in the season whilst the other two species remained green, although the growth of S.50 virtually ceased. From this it appears that each species can use, or compete for, quite different amounts of soil moisture, before depletion of soil moisture restricts further losses from the grass. These amounts, which determine the full extent of the intensity of competition for soil moisture which each of the grasses can impose on the trees, will depend on the root depth of the grass species. It is therefore important to know over what soil depth each of the grasses, under a given management, is able to compete with the trees for soil moisture.

Fig. 2 gives information on the soil moisture losses from successive soil layers, each 6 in. deep, to a depth of 3 ft. under the three swards. The amount of available water estimated to be held in each 6 in. depth increment is shown. The wilting point values, needed to assess the total available reserves, have been estimated from field data. The moisture deficits developed in each 6 in.

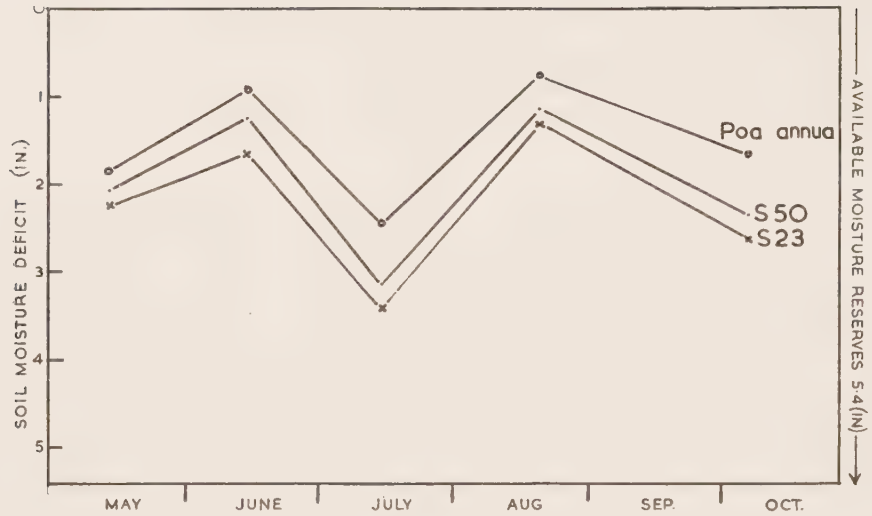

FIG 1.
Total Soil Moisture Deficits, 1954.

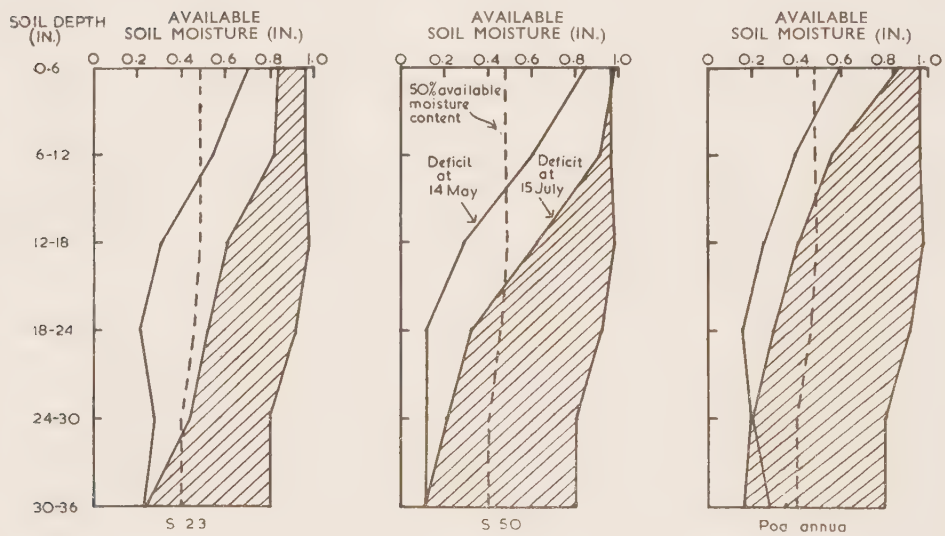

FIG 2.
Deficit Distribution, 1954.

depth are shown for two occasions only, the 14th May, near the beginning of the season, and the 15th July, when the highest deficits were determined. The shaded part of each diagram represents the available reserves remaining in the soil at the 15th July.

The drying patterns observed under the three swards are probably partly due to the natural rooting habit of the grass species and partly due to a uniform cutting treatment applied to all swards (3 cuts before the 14th May and 9 before the 15th July), which in effect would tend to be least drastic for the most vigorous sward, the S.23 perennial ryegrass.

The deficit values for each 6 in. depth of soil indicate that drying was more uniform through the soil depth under S.23 than under the other two swards, which suggests a deeper root system associated with S.23. The intensive drying to 12 in. under S.50 suggests a compact but shallow root system, whilst a very shallow root system confined chiefly to the top 6 in. of soil is indicated for the natural sward.

Although it is not possible to judge precisely where the grass root influence becomes negligible, because drying by fruit tree roots is also involved, it appears that the influence of the S.23 roots is

probably 6 in. deeper than the S.50 and 18 in. deeper than the natural sward. Thus under climatic conditions demanding full exploitation of the soil moisture within the grass root zone, the deficit under S.50 could be from 0·5 to 1·0 in. less and under the natural sward from 1·5 to 2·5 in. less than that under the S.23. This was confirmed during the summer season of 1955, when considerably higher soil moisture deficits were developed than during 1954. It was found that the differences between maximum deficits for the season were 0·61 in. and 1·63 in. more for the S.23 than for the S.50 and the natural swards respectively. The drying pattern under each type of sward was similar to that of 1954, a marked decrease in deficit occurring from 6–12 in. under the natural sward and from 18–24 in. under the S.50. Hence it is clear that, during periods of low rainfall, the trees in the S.50 and natural swards have more water to meet their requirements for growth, fruit development, and transpiration purposes, than have the trees in the S.23 swards.

However, tree growth and fruit development can be affected by soil moisture supply before exhaustion of the soil moisture reserves occurs. As a soil dries, the remaining soil moisture becomes progressively less easily available and at a given deficit, the availability, rather than the amount, of the remaining reserves of moisture is considered to be of greatest importance in respect of tree growth and fruit development. The relative availability of soil moisture depends primarily on the tension or force with which it is held by the soil. Decreasing water content in a soil results in an increasing soil moisture tension and in the soil under study, a fine sandy loam, the soil moisture tension increases relatively slowly with water withdrawal up to about 50 per cent of the available reserves. Further water removal gives rise to rapidly increasing soil moisture tensions. In a study of the behaviour of apple trees growing under conditions where soil moisture tensions have been controlled within certain limits, observations are that with increasing tensions, even at tension levels substantially below one atmosphere, growth is first retarded, and is then followed at higher tensions by a check to the development of full fruit size. Hence in this soil, and soils of similar texture, it appears that a critical level of soil moisture depletion occurs when about half of the available soil moisture reserves has been used.

A dotted line has been drawn in each diagram of Fig. 2 to represent 50 per cent reserve depletion and it can be seen that by mid-July the deficit under S.23 had exceeded the ' critical level ' at all depths except 30–36 in. The deficit under S.50 exceeded the level only to a depth of 18 in. Thus, although there was very little difference between the total deficits under S.23 and S.50, the soil moisture conditions below 18 in. depth under the S.50 were more favourable for tree growth and fruit development than under the S.23. The natural sward offered the best soil moisture conditions for tree growth and full fruit size development, for serious depletion of soil moisture reserves occurred only to a depth of 12 in.

Discussion

The season of 1954 was an unfavourable one for showing maximum soil moisture deficits capable of being developed by the grass species S.23 perennial ryegrass, S.50 timothy, and annual meadow grass. The deficits that were observed however, indicate that competition with fruit trees for soil moisture would be to the greatest depth under S.23, rather shallower under S.50, and considerably shallower under annual meadow grass. The effect of this competition to greater depth under the more vigorous grass leads to less available water for tree use and to soil moisture tensions less favourable for tree growth and fruit development.

A high annual application of ammonium sulphate at the rate of 6 cwt. per acre, together with frequent mowing of the swards shown by Rogers, *et al.* (1948) to reduce competition for nitrogen to a minimum, was expected to largely eliminate any differential harmful effects of the grasses on tree growth and cropping due to competition for nitrogen. However, observations on the trees (Greenham, unpublished) suggest that this was probably not achieved and that S.23 reduced the nitrogen status of the trees compared with the other swards in the trial.

The differential competition for nitrogen may have been in part a direct effect of the swards, although differences in nitrogen uptake may well have been caused by the observed differences in soil moisture status.

It remains to be seen to what extent the effects of the more vigorous sward on soil structure are greater than those of the weaker sward. Compensatory factors like increased infiltration of rain into the tree root zone and a greater capacity of the soil to hold water at low soil moisture tensions due to structural changes in the soil, may eventually offset the greater competitive effect for soil moisture observed during the early years of establishment of the vigorous sward in the orchard.

Summary

Under a uniform and frequent cutting treatment in an orchard, S.23 perennial ryegrass, S.50 timothy, and annual meadow grass, were found to dry the soil to different depths. The depth of

drying was greatest with S.23 and least with annual meadow grass, S.50 being intermediate. These differences were shown to be sufficient to account for a differential checking effect on young Laxton's Fortune trees on M.II in their first few years following grassing down, on the basis of competition for water. Differential competition for nitrogen, which may also have been involved in the checking effect, may have been, at least partially, an indirect result of the observed soil moisture differences.

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WEATHER CONDITIONS DURING 1955

By G. F. TROWELL

East Malling Research Station

The past year has been quite an eventful one for weather. An exceptionally late dry spring was followed by a month of cool wet weather, but the later summer months were dry, with temperatures and sunshine above average. Considerable heavy rainfalls occurred throughout the year together with a large number of thunderstorms.

Mean maximum screen temperatures during the first half of the year were generally below average, only April having temperatures above the average of the past ten years. During May the maximum temperatures were 4° F. below average, while July to September were all above average. Mean minimum screen temperatures followed a similar pattern to the maximum temperatures, except that September was below the average. The highest screen temperature was 85° F., recorded on 22nd August, and the lowest 16° F., on 15th January.

Ground frosts were more numerous than in the past two years ; 95 were recorded (the greatest number being in March), compared with 81 in 1954 and 68 in 1953. No serious late frosts occurred, although one was recorded on 22nd May, when the screen temperature fell to 31° F. with a grass temperature of 28° F., lasting for a short while between midnight and 0100 hours. A ground frost was almost experienced on 11th June when the grass temperature fell to 32° F., with a screen temperature of 34° F., which lasted for only a short while at 0400 hours. Spring was extremely late, the first blossoms appearing on Myrobalan on 3rd April (Fig. 1), by which time last year full blossom was past. Soil temperatures in March were generally lower than of recent years and were even lower than in 1947, when spring was extremely late. This, together with the low mean screen temperatures during March, possibly contributed to the lateness of the early part of the blossoming season.

Sunshine during the year amounted to 1,632 hours, 69 hours above the 25-year average and 280 hours above last year's total. Only January, June, and November had sunshine below average ; during January sunshine was recorded on only 9 days. The sunniest day of the year was on 30th May when 14·9 hours were recorded.

Rainfall during the year totalled 25·24 inches, 0·86 inches below the 35-year average, but the distribution was again unusual. April set up a new record for East Malling as the driest April since records began in August, 1914. Rain was recorded on only 3 occasions, and those were during the first 7 days of the month, giving a total of 0·20 inches. The previous driest April was last year, when 0·38 inches were recorded. May, on the other hand, was the wettest May since 1942. Dry conditions were experienced during July and August with practically all the rain in July falling on one occasion. October was the wettest month of the year, with some heavy downpours ; the total rain recorded was 4·63 inches, which fell during 10 days, and of this, 3·49 inches fell in 4 days. The heaviest day's rainfall for the year (2·23 inches) occurred on 21st October. This set up the second record for 1955 as the heaviest day's rainfall since records began in August, 1914. (The previous highest was 1·85 inches recorded in August, 1944.) December had rain on 20 days, the highest number of days on which rain was recorded in any month.

Thunderstorms were more numerous than of recent years, 11 occurring over or in the neighbourhood of the Station during May, July, August, and November. Several severe storms were recorded, especially one which began at 2100 hours on 17th July and lasted until 0300 hours on 18th July. Total amount of hail and rain recorded during this storm was 1·68 inches, and some larger amounts were recorded within a few miles of this Station.

Snow and sleet occurred on 27 occasions during January, February, and March, the ground being continuously snow-covered for 9 days between 16th and 24th February. Once again no snow fell during the latter months of the year.

Strong winds persisted throughout much of the first half of May, giving poor pollination conditions during the period when varieties such as Bramley and Cox were in blossom (Fig. 1). Gale force winds of over 40 m.p.h. were recorded twice (23rd and 24th March) and strong winds of ' Force 6 ' to ' Force 7 ' 21 times, of which 6 were in May.

The Station was inspected by an officer of the Meteorological Office during the year and received a satisfactory report.

Newlands Farm, Throwley

Mean maximum screen temperatures were once again below those at East Malling, while the mean minimum screen temperatures were the same or slightly above, as in previous years. The highest

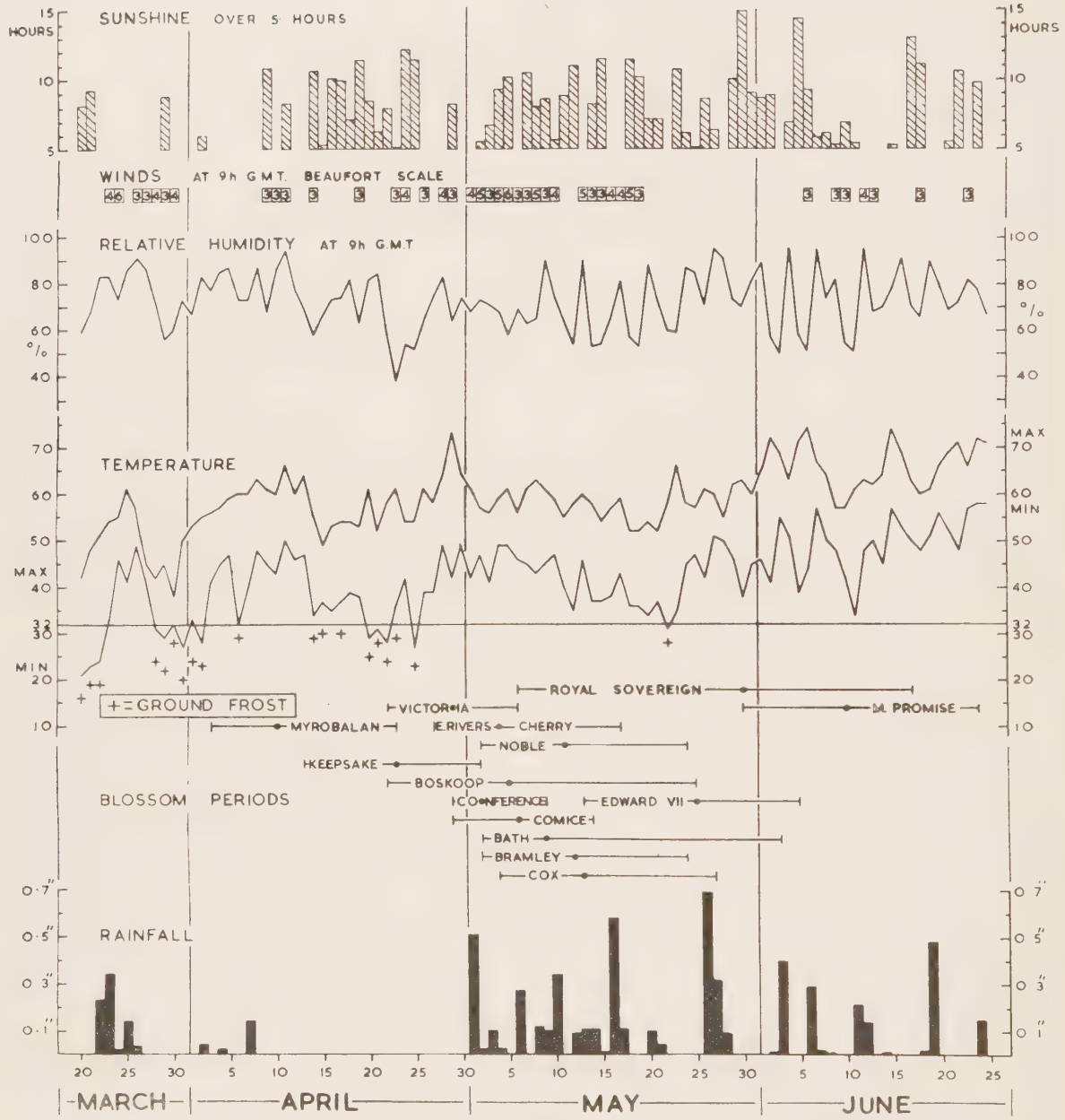

FIG. 1

Diagram showing the weather recorded during the blossoming season at East Malling Research Station in 1955.

temperature was 82° F., recorded on 22nd August, and the lowest 21° F., recorded on 20th and 28th February and 2nd March. As usual sunshine was higher, this year by 77 hours. Rainfall was again considerably higher, 7·82 inches more than at East Malling. It is interesting to note that last year it was higher at this sub-station by 7·87 inches. Thunderstorms and distant thunder were recorded 21 times. Snow and sleet were recorded 41 times, the ground being continuously snow covered for 9 days between 6th and 14th March, when snow reached a depth of 9 inches with considerable drifting. Gale force winds were recorded on a number of occasions.

Acknowledgements

The writer wishes to thank Mr. C. H. W. Slater for his assistance during the year. Mr. J. Cronk (by courtesy of T. Neame, Esq.) was responsible for records on Newlands Farm, and his co-operation is gratefully acknowledged.

EAST MALLING

Month	Temperature in Screen					Number of Ground Frosts	Rainfall			Sunshine			Soil Temperatures			
	Mean maximum	Mean minimum	Highest	Lowest	Mean		Total in inches	Heaviest fall in a day	35* years' average	Total hours	Average per day	25 years' average	4 inches	8 inches	2 feet	4 feet
JANUARY	41·5	30·9	54	16	36·2	15	3·45	0·96	1·96	29·2	0·9	47	34·9	36·0	39·0	42·4
FEBRUARY	40·6	31·3	53	19	36·0	17	1·80	0·38	1·85	83·5	3·0	68	35·2	36·2	39·0	41·4
MARCH ..	44·5	31·2	61	21	37·9	23	1·11	0·34	2·01	136·8	4·4	123	35·8	36·2	38·0	39·5
APRIL ..	58·4	39·2	73	27	48·8	11	0·20	0·14	1·65	179·8	6·0	152	48·4	47·2	46·8	44·9
MAY ..	58·2	42·0	66	31	50·1	1	3·73	0·69	1·67	224·8	7·3	200	53·0	51·1	51·5	49·5
JUNE ..	66·6	49·8	74	34	58·2	0	1·91	0·48	2·04	179·7	6·0	222	61·2	59·3	58·2	54·4
JULY ..	72·4	53·5	84	45	63·0	0	1·79	1·68	2·19	227·3	7·3	208	65·7	64·9	64·3	59·9
AUGUST ..	73·7	53·5	85	40	63·6	0	0·98	0·21	2·19	199·9	6·4	194	66·2	65·2	65·5	62·2
SEPTEMBER	66·7	47·5	76	37	57·1	0	2·50	1·47	1·98	160·4	5·3	147	58·3	58·0	60·9	60·6
OCTOBER	56·5	39·0	67	26	47·8	8	4·63	2·23	3·11	122·9	4·0	105	47·2	48·8	52·4	54·6
NOVEMBER	50·7	38·8	61	21	44·8	8	1·02	0·25	2·79	41·0	1·4	55	42·9	44·1	46·9	49·5
DECEMBER	48·7	36·0	56	24	42·4	12	2·12	0·52	2·66	47·0	1·5	42	40·2	41·3	43·3	45·8
TOTALS ..						95	25·24		26·10	1632·3		1563				

SUB-STATION, NEWLANDS FARM, THROWLEY

															12 inches	
JANUARY	40·2	31·5	50	22	35·9	16	3·92	0·83	26·8	0·9		36·2	37·5	39·8	43·8	
FEBRUARY	38·5	30·1	51	21	34·3	20	2·09	0·45	85·6	3·1		35·6	37·5	39·4	42·2	
MARCH ..	41·8	30·7	61	21	36·3	24	4·05	0·89	150·0	4·8		35·0	36·1	37·2	39·6	
APRIL ..	55·0	40·1	71	31	47·6	8	0·22	0·17	176·2	5·9		46·7	46·8	45·5	43·5	
MAY ..	56·1	41·9	64	34	49·0	4	3·54	0·75	231·8	7·5		50·9	51·2	50·3	47·7	
JUNE ..	64·4	49·2	71	40	56·8	0	2·12	0·50	183·7	6·1		58·6	57·6	55·8	51·7	
JULY ..	68·6	53·6	80	46	61·1	0	1·02	0·82	222·9	7·2		62·5	62·0	59·9	56·0	
AUGUST ..	70·9	54·4	82	45	62·7	0	4·21	1·13	211·4	6·8		62·2	62·5	60·9	58·0	
SEPTEMBER	64·6	50·3	71	43	57·5	0	1·85	0·87	170·5	5·7		57·5	58·6	58·8	58·1	
OCTOBER	56·0	41·3	66	29	48·7	7	5·98	2·29	145·6	4·7		49·2	51·3	52·9	54·6	
NOVEMBER	49·0	40·4	60	27	44·7	9	1·18	0·42	51·7	1·7		44·2	46·1	48·2	50·6	
DECEMBER	47·5	37·2	53	25	42·4	11	2·88	0·41	53·3	1·7		40·6	42·2	43·8	46·9	
TOTALS ..						99	33·06		1709·5							

* Weighted averages for the 35-year period 1881–1915, as used in the Monthly Weather Report of the Meteorological Office.

STATISTICS

STUDIES IN THE MEASUREMENT OF APPLE TREES

III. THE USE OF BRANCH GIRTHS AS A SUBSTITUTE FOR THE TRUNK GIRTH

By S. C. PEARCE

In two earlier papers of this series (Pearce, 1952 ; Pearce and Davies, 1954) consideration has been given (*a*) to the value of trunk girths as an estimate of tree size, and (*b*) to the best height for measuring them. Sometimes, however, the trunk girth cannot be measured, on account either of the crotch being nearly buried or the trunk being split or some other abnormality. In these circumstances it is tempting to measure the branch girths instead and to try to integrate them into a single value to replace the trunk girth. It should be emphasized from the beginning that this is necessarily an uncertain procedure. For one thing, branches commonly fork at such varying distances from the crotch that no standard position for measuring them can be suggested. For the purposes of this study all girths have been measured as near the crotch as possible consistently with the cross-section of the branch being circular. Where the main branch has forked so soon that no suitable place was to be found, two sub-branches have been measured instead and regarded as main branches. However, the judgement of what was and what was not circular was subjective, and might have been decided differently by a different recorder. Another difficulty is that, in general, trees with abnormal trunks rarely have a full complement of branches ; for purposes of this paper trees from which main branches have been removed, even though the loss took place a long time ago, have been ignored. Experience in this investigation suggested that even very old scars can be important. Nevertheless, despite these difficulties, the writer has found use for branch girths on occasion, and the work to be described is put forward as a practical recording method.

Quantities studied

Two ways were examined of integrating branch girths. One was to square them all and to add the squares, the result being termed P^2 ; the other was to add the branch girths and to divide by the square root of their number to give the quantity Q. It will be seen that P was the girth of a cylinder having the same area of cross-section as that of all the branches together, and Q was an approximation to P adopted for ease of computation. To give an example, if there were three branches, their girths being 10·1, 12·0, and 14·6, then

$$P=\sqrt{10\cdot1^2+12\cdot0^2+14\cdot6^2}=21\cdot4, \text{ and}$$
$$Q=(10\cdot1+12\cdot0+14\cdot6)/\sqrt{3}=21\cdot2.$$

Adapting the notation of a previous paper (Pearce and Davies, 1954), trunk girth 9 inches above the graft union will be written G, and that immediately below the crotch, K. Throughout, small letters will be used to denote the logarithms of the quantities represented by the corresponding capitals.

Statistical approach

The statistical approach throughout will be to consider the equation

log (actual trunk girth)$=a+b$ log (estimate of trunk girth).

Three tests will be used in succession,

(i) To find out if the data are suitable for study by later tests.
(ii) If so, to find if the treatments affect the value of b.
(iii) If not, to see if they affect a.

These tests were described by Welch (1935), and were those used in the two earlier papers of this series.

Material and records

Use was made of data from five trials, numbered so as to continue the series of the previous papers, namely :

R4. Twenty-two trees of Cox's Orange Pippin, 24 years old, three on M.I, eight on M.II, five on M.IX, and six on M.XIII. *Records*.—Trunk girth nine inches above the union (*G*) and just below the crotch (*K*), and branch girths.

R7. Twelve trees of Lane's Prince Albert, 36 years old, six on M.II, and six on M.XVI. *Records*.—Trunk girth nine and nineteen inches above the union (*G* and *K* respectively).

P3. Twenty-seven trees of Worcester Pearmain, 31 years old, on seedling rootstocks. Four were unpruned in their early years, eight were long-spur pruned, eight short-spur pruned, and six regulated. *Records*.—A lower girth mark had been chosen when the trees were about nine years old to show the minimum girth at that time. At the same time a mark had been made just below the crotch. Girths at these two levels were termed *G* and *K* respectively. Branch girths also were measured.

P4. Eleven similar trees of Grenadier, five long-spur pruned, and six short-spur pruned. *Records*.—As in Trial *P3*.

M3. Forty-two trees of Cox's Orange Pippin on M.I, 17 years old. Throughout their lives half these trees had received more potash than the others, and this had built up a large difference in tree size between the two groups. There were other manurial differences, but these had had comparatively little effect on size of tree and are here ignored. *Records*.—Trunk girths at nine and eighteen inches above the graft union (*G* and *K* respectively), and branch girths.

In all these trials the trees had the crotch from 20 to 24 inches above the graft union. Branches with a girth of less than five centimetres were ignored.

Results

First of all, for each trial correlation coefficients were worked out between either *g* or *k* on the one hand and either *p* or *q* on the other to see if there was a sufficiently close relationship between the trunk girths and the quantities intended to estimate them for the study to be worth undertaking. These coefficients are set out in Table I, and show that the association is very close.

TABLE I

CORRELATION COEFFICIENTS BETWEEN *g* AND *k* (THE LOGARITHMS RESPECTIVELY OF LOWER AND UPPER TRUNK GIRTHS) AND *p* AND *q* (THE LOGARITHMS OF TWO QUANTITIES DERIVED FROM BRANCH GIRTHS)

Trial	*g* and *p*	*k* and *p*	*g* and *q*	*k* and *q*
R4	+0·954	+0·944	+0·941	+0·924
R7	+0·957	+0·950	+0·933	+0·935
P3	+0·959	+0·955	+0·965	+0·960
P4	+0·975	+0·982	+0·979	+0·983
M3 ..	+0·968	+0·979	+0·965	+0·972

Next, all sets of data were tested and found to be suitable for further investigations. Then they were examined for evidence that the treatments, whether of rootstocks, pruning methods, or of manuring, had affected the value of *b*, but none had had any significant effect (P=0·05). These values of *b* are set out in Table II.

TABLE II

REGRESSION COEFFICIENTS OF *g* AND *k* (THE LOGARITHMS RESPECTIVELY OF LOWER AND UPPER TRUNK GIRTHS) UPON *p* AND *q* (THE LOGARITHMS OF TWO QUANTITIES DERIVED FROM BRANCH GIRTHS)

Trial	*g* upon *p*	*k* upon *p*	*g* upon *q*	*k* upon *q*
R4	+0·913	+0·900	+0·868	+0·850
R7	+0·841	+0·748	+0·866	+0·777
P3	+0·970	+0·941	+1·000	+0·970
P4	+0·889	+0·884	+0·875	+0·889
M3 ..	+0·899	+0·944	+0·934	+0·977

For presentation of the effects of treatments upon *a* it will be easier to take each sort of trial separately.

First, for the rootstock effect, in Trial *R4* there was some suggestion, nearly significant at the 5 per cent level, that M.IX was giving a lower value of *K* than the other rootstocks for comparable

branch sizes, whether these were measured by P or by Q. Relative values for K for similar branch girths as measured by P were :

M.IX, 95·2 ; M.I, 100·0 ; M.II, 100·4 ; M.XIII, 103·8.

This result could have arisen in several ways, however ; thus M.IX has a notably more spreading habit, also it is less vigorous and consequently required a larger covariance adjustment with greater expectation of error if b had for any reason been estimated poorly. For these reasons, some confirmation of the result was called for, and Trial *R7* was added to investigate the behaviour of two rootstocks, M.II and M.XVI, which show a much smaller range of vigour, and have very similar crotch angles in the scion, yet in the two earlier studies give different relationships between any pair of growth records investigated. Here, the values of K for similar values of P were greater for M.II (100·4) than for M.XVI (90·6) the difference being significant (P=0·05). Where Q was substituted for P, the difference was nearly significant. It thus appears that the values of a may depend upon the rootstock. For the estimation of G from P, even more marked differences were observed, the figures being :

M.IX, 91·6 ; M.I, 100·0 ; M.II, 100·3 ; M.XIII, 101·8.

This is to be expected in the light of what is known about the effects of rootstocks upon trunk taper (Pearce and Davies, 1954).

There was no suggestion that pruning had any effect upon a, whether it was K or G that was being estimated from P or Q in Trials *P3* or *P4*.

For manuring, the results were not quite as clear, there being a suggestion in the estimation of K from P that the trees with high potash were 2·7 per cent larger in K for comparable branch girths than those with low potash. This difference was nearly significant at the level, P=0·05, but did not appear in the estimation of K from Q or of G from P or Q. If the treatments were affecting the relationship, the disturbance could hardly have been large.

Recommendations

Primarily this was an investigation to find a value based on branch girths that could be used as a substitute for the trunk girth. Such a quantity has been found in P and Q, both of which are highly correlated with trunk girth and which, for the particular manurial and pruning treatments studied, were affected in the same way as the values they were intended to replace. Of the two, Q is the more easily computed ; it is correlated with the trunk measurements nearly as well as is P, and its relationship with trunk girths is less affected by treatments, though this is perhaps no more than a coincidence. Altogether, the use of Q is recommended.

It will sometimes happen that some of the trunk girths will be unobtainable but not others. On such occasions it would be permissible to use G where known and Q otherwise, and to adjust for the difference by means of covariance upon a variate made equal to *zero* when G was used and to *one* where Q was. Strictly it would be necessary first to multiply q by the regression coefficient of g upon q, and Table II shows that in general this may be taken as about 0·9. In both this paragraph and the preceding one it is assumed that the analysis of variance is to be carried out not on girth but on its logarithm (Pearce, 1943).

In rootstock trials Q will not tell the same story as G ; there is some evidence that rootstocks which give a small value of G in relation to weight of tree also have a small value of G in relation to Q (cf. Table I, Pearce, 1952). That being so, the story told by Q is probably the more reliable, and, in any event, that of G is not recommended (Pearce, 1952).

Discussion

From the three papers of this series a pattern of results has emerged. Thus, for trees on different rootstocks, it has appeared that certain rootstocks give trees that are larger in the branches than would be expected from the top of the trunk, and larger at the top of the trunk than would be expected from the bottom, and also heavier in the head for its trunk measurements. It would, however, be wrong to think of this as an indication of vigour, for, though this effect is marked with trees on M.XVI, it is not less marked with those on M.IX, while trees on M.I go to the other extreme. There is a suggestion, incidentally, that trees on M.XIII do not always behave exactly as the rule would indicate.

It will, perhaps, be of value to summarize the results of the three papers. First, applications of potassium on a soil deficient in that element have brought about very large differences in the size of the trees, yet in no instances have the relationships under study been affected thereby. It is as if the tree had its own laws to determine the relative growth rates of its various parts and, when enabled to grow larger by additional potassium, did so consistently with those laws. It is of interest to enquire if a study of other elements, especially nitrogen, would have led to a similar conclusion,

but no direct evidence is to hand. It may be noted, however, that in the manurial trials factors other than the level of potassium were ignored, yet the correlation coefficients found were not very different from those in other trials, so the factors disregarded, namely varying applications of nitrogen and phosphorus, cannot have had a very large effect on the relationships, though the nitrogen especially had affected growth and health. Nevertheless, the question is of some importance and has yet to be answered.

Further, differential pruning applied to the head altered the total weight of the tree in relation to its trunk girth, but the relationships between trunk and branch girths were unaffected. Plainly, pruning affects relationships with the part of the tree pruned, but it does not appear that it alters the relative growth of the other parts. It should be noted that all the trees studied were of open centre form, and that no information has been presented about trees shaped differently.

On the other hand, rootstock effect on the tree was evidently quite different, for it brought about changes in all the relationships studied.

The effect of scion on these relationships has not received much attention, though it was suggested in the first paper that in the equation,

$$(\text{Weight of tree}) = A\ (\text{Trunk girth})^b,$$

the value of b was a varietal characteristic, and for Worcester Pearmain it had an unusually low value. From Table II of the present paper it appears that the value of b in the relationship,

$$(\text{Trunk girth}) = A\ (\text{Integration of branch girths})^b,$$

was high for Trial $P3$, in which Worcester Pearmain was again the scion variety. Although these two results are in good agreement, it would not be wise to build much upon them until more is known. If, however, the values of b in these relationships do depend to an important extent upon the variety, the comparison of scions is evidently going to be very difficult.

These methods were developed to provide information on the measurement of trees, and for that reason regression methods were used, the problem being to assess the changes in one quantity by estimation from changes in another. In all three papers, however, the correlation coefficients have been so high that these regression lines must be virtually identical with the various lines of best fit that might have been used to study the underlying fundamental relationships ; consequently the results have a wider application than was originally intended. Thus, it is of interest to notice how different was the effect of rootstocks on the relationships studied from that of pruning or of fertilizing with potash ; plainly the mechanisms must be quite different. This particular result might have been expected, but the method might well prove of value in studying and comparing the mechanisms of various treatments where information was otherwise hard to come by.

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Summary

A search is described for some quantity based on branch girths that may be used instead of trunk girth where the latter cannot be measured. It is shown that if the branch girths larger than 5 cm. are added together and divided by the square root of their number, a satisfactory substitute is obtained, though one that is of doubtful value in rootstock trials.

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SOIL ACIDITY IN RELATION TO TRUNK GIRTH OF APPLES

By D. A. HOLLAND

It is generally agreed that soil differences can cause tree variation and this may be minimized by a suitable arrangement of blocks. There will remain variation within the blocks and this can sometimes be reduced by adjustment upon estimates of characteristics of the soil known to be related to fertility or to affect tree growth.

What is needed to reduce further this variation in a trial is a measurement, other than those already referred to, that can be used as an independent variate by which growth records can be adjusted through an analysis of covariance. The number of characteristics that could affect the growth of a tree is large and most are difficult to assess, but some also involve a variation in soil pH and this is relatively easily measured. Goode (1954) has cited an example of correlation between soil pH and trunk girth of apples. The general existence of such a correlation would make it possible to use the soil pH of each plot in a trial to adjust trunk girth, provided that pH was not affected by the treatments, and thus to increase the precision of a trial by $\left(\frac{1}{1-r^2}\right)$ times, where r is the correlation coefficient. Thus, in the example referred to by Goode the increase would be 1·4 times and 2·1 times for the two trials concerned, a worthwhile increase in precision.

The analysis of covariance requires that soil pH be independent of the experimental treatments as well as correlated with tree growth. The first requirement can be fulfilled by measuring the soil pH before the treatments are applied. For the purpose of this investigation, where only the relationship between soil pH and tree growth is in question, this requirement can be waived.

The investigation to be described falls into two parts :

First, it would be a waste of time to try to explain variation in growth in a field by differences in soil pH if these were merely the result of errors of sampling, measurement, etc., and a method is suggested for finding out if a field is in fact heterogeneous in respect of soil pH. The problem may be expressed more precisely in the following terms.

Suppose that p is the true soil pH, and g is the trunk girth to be expected from it following the relationship $g=a+bp$ where a and b are constants. Suppose also that p is actually observed as P on account of a sampling error with variance σ_p^2, and g is observed as G on account of errors of measurement or the relationship not being exactly what it is assumed to be, the variance from these sources being σ_g^2. Then, if p varies with variance σ_o^2, it follows that the variance of P will be $(\sigma_o^2+\sigma_p^2)$, and that of G, $(b^2\sigma_o^2+\sigma_g^2)$. The covariance of P and G will be $b\sigma_o^2$ so the correlation coefficient between them will be

$$r_{PG}=\frac{b\sigma_o^2}{\sqrt{(\sigma_o^2+\sigma_p^2)(b^2\sigma_o^2+\sigma_g^2)}}$$

From this it can be seen that as σ_p^2 increases relative to σ_o^2 the value of r_{PG} approaches zero.

Following this, a study is made of the effect of genuine changes in soil pH on tree growth as measured by trunk girth. It may be that the relationship between p and g suggested above can be improved upon.

Data and material

Data were used from all the trials at East Malling from which soil pH values for each plot and girth records from each tree were available.

A list of the trials used, with a brief description of each, is given in Table I. Under the column heading ' Reference ' the East Malling plot number is given in each instance in order that reference can be made, if desired, to the extended descriptions given by Walker (1954) and to the soil map of Furneaux (1954).

Trials 3 and 4 have previously been described (Goode, 1954) and attention drawn to the distinct change in soil pH across the field corresponding to the division of the field dating from before 1789 until 1917 (Pearce and Greenham, 1955). In Trials 3a and 4a the part of the field to the south of this division was not included, only the northern part, with its more limited range of soil pH values, being examined. Trials 7a and 7b in reality constituted a single trial with 4 trees of each variety per plot, but each variety has here been considered separately.

With the exception of Trials 5a and 5b the treatments have all been of a type likely to affect

TABLE I

DESCRIPTION OF THE TRIALS USED IN THE INVESTIGATIONS

Trial	Variety and rootstock	Type of trial	Age	Plot size	Mean soil pH	Range of pH (units)	Reference
1	Cox/M.VII	Soil management	7 years	1 tree	5·55	0·66	L8
2	Cox/M.XII	Manurial	24 years	1 tree	6·28	1·37	C2
3	Laxton's Superb/M.II	Soil management	5 years	2 tree	7·25	1·99	C11
3a	Laxton's Superb/M.II	Soil management	5 years	2 tree	7·78	0·47	C11
4	Laxton's Fortune/M.II	Soil management	5 years	2 tree	7·32	2·07	C11
4a	Laxton's Fortune/M.II	Soil management	5 years	2 tree	7·89	0·39	C11
5a	Cox/M.VII	Uniformity	5 years	1 tree	5·19	0·23	D3
5b	Worcester/M.VII ..	Uniformity	5 years	1 tree	5·63	0·25	D3
6	Cox/M.IX	Soil management	14 years	3 tree	6·94	0·40	M2*
7a	Cox/M.IX	Soil management	12 years	4 tree	7·41	0·37	E35*
7b	Beauty of Bath/M.IX	Soil management	12 years	4 tree	7·41	0·37	E35*

* Trial grubbed before Walker's description was prepared.

soil pH. Consequently, treatment differences were eliminated in calculating correlation coefficients, which are all based on variation within treatments ; the ranges of soil pH given in Table I are the average within treatment ranges.

The pH determinations were made on a composite sample of borings from each of the four corners of a plot, the position of each boring being half way between the corner of the plot and the nearest experimental tree. The growth of the trees was represented by the mean of the girths of all the trees in a plot.

The soil pH for the depth 0–12 inches was always available, and sometimes also for the depths 0–6 and 6–12 inches. Preliminary investigation showed there to be no reason why the 0–12 inch depth should not be used throughout and this was done.

I. Detection of variability in respect of soil pH

The sampling error of soil pH determinations

The sampling error of soil pH can be divided into two main sources. First there is the experimental or laboratory error and secondly there is that error arising from the fact that the borings examined are only a sample of the whole area of soil. Raupach (1954) showed the 5 per cent limits of a determination to be $\pm 0{\cdot}09$ units, while Hemingway (1955) gives them as $\pm 0{\cdot}088$ units. Such errors are sufficiently small, compared with the variation of soil pH usually encountered, to be disregarded. The variability of soil pH has been assessed by several workers, but generally the method of assessment has been based on a systematic sampling and not a random one, and the figures obtained must be regarded as over-estimates. These previous assessments are summarized in Table II. Where the standard error was not given in the original text, it has been computed from the data given. It should be noted that the last two assessments in this table refer to samples drawn from a much larger area (several acres) than the others and might be interpreted as representing positional variation as much as sampling error proper.

TABLE II

SUMMARY OF PREVIOUS ASSESSMENTS OF THE VARIABILITY OF SOIL pH

Reference	Source of sample	Method of sampling	Sampling error*
Downes and Beckwith (1951)	Grazed land	12 from a 1-foot grid	$\pm 0{\cdot}206$ $\pm 0{\cdot}338$
Raupach (1951)	Grazed land	4 in a 33-inch square	$\pm 0{\cdot}439$†
,, ,, ...	,, ,,	7 in a 38-inch square	$\pm 0{\cdot}497$†
,, ,, ...	,, ,,	4 in an 18-inch square	$\pm 0{\cdot}511$†
.. ,, ...	,, ,,	5 in a 36-inch square	$\pm 0{\cdot}433$†
Hemingway (1955)	Limed land	24 dispersed over field	$\pm 0{\cdot}45$
,, ,, ...	Unlimed land	24 dispersed over field	$\pm 0{\cdot}20$

* Standard error of an individual observation.
† Computed from data given in original text.

Hemingway (1955) has stated that the sampling error of pH is greater on limed soils than on unlimed soils and also that grazing is similar to liming in this respect. It appears then, that any method of treating the land which might affect its pH will increase the sampling error of pH samples taken from it, and on this basis the application of sulphate of ammonia, or the ploughing in of cover crops, could be expected to increase the sampling error.

In order to test this and also to make a more accurate estimate of the sampling errors in the trials here considered, further soil samples were taken on Trials 2 and 5a. This time two borings were made at random at each corner of the plot within a foot of the normal sampling position and separate pH determinations were made on each. For Trial 2 sampling errors were computed separately for those plots receiving sulphate of ammonia, and for those not receiving it. The results are shown in Table III.

TABLE III

SAMPLING ERROR OF pH AND RATE OF APPLICATION OF SULPHATE OF AMMONIA

Trial	Sampling error	Cwts. of amm. sulph. per acre per year over the preceding two years
5a	±0·158 units	4
2 (without N)	±0·074 units	0
2 (with N)	±0·410 units	6

In the light of these results and the previous work the assumption that the sampling error for soil pH is dependent on how the land has been treated is not unreasonable. The sampling errors to be expected are of the order of :

up to ± 0·07 units for untreated land.

up to ± 0·15 units for moderately treated land (small applications of lime or sulphate of ammonia).

up to ± 0·4 units for heavily treated land (large applications of lime or sulphate of ammonia, ploughing-in of cover crops, etc.).

Of the trials studied in this investigation, annual dressings of sulphate of ammonia as high as 6 cwt. per acre had been given to Trial 1 for four years and to Trials 3, 3a, 4, and 4a for 2 years prior to the soil pH records being taken. For five years Trial 5 had been receiving annual dressings of only 3 cwts. per acre, but the treatments involved the ploughing in of annual cover crops, while on Trials 7a and 7b, which in each of the preceding two years had received dressings of only 1½ cwt. per acre, the cover crops were ploughed in very shortly before the soil samples were taken. These trials might therefore be classified as heavily treated with an expected sampling error of up to ±0·4 units. On the other hand, Trials 5a and 5b had been given an annual dressing over the preceding three years of only 4 cwt. per acre of sulphate of ammonia, while Trial 2 had only been receiving 3 cwt. per acre per year over the ten years preceding sampling. Thus these trials might be regarded as moderately treated, with a sampling error of up to ±0·15 units.

A preliminary test of the likelihood of detecting a correlation

It has been shown that a correlation between P and G can only be detected when the variance of P, $(\sigma_o^2+\sigma_p^2)$, from the trial, appreciably exceeds the appropriate sampling variance (σ_p^2). It would therefore be advantageous to be able to determine $(\sigma_o^2+\sigma_p^2)$ from a few sample borings, for then, with the expected value of σ_p^2 derived from the history of the land, it would be possible to judge whether a full recording of pH was likely to show a worthwhile correlation. One common way of roughly determining a standard error is to take a preliminary sample, determine its range, i.e., the difference between the extreme values, and use the table of Pearson (1942). Table IV has been derived from Pearson's table, and it shows the minimum ranges that might be expected in a sample of five plots for different sampling errors when σ_o is zero ; five being the number of observations in a single sample which gives the best estimate (Davies and Pearson, 1934). Thus, if the sampling error were really 0·07 the range would be less than 0·03 on one occasion in 1,000, less than 0·05 on one occasion in 100, and so on. It will be noted that for the five per cent level it is a rough rule that the range will be at least equal to the sampling error σ_p. Only if the range in observed soil pH is appreciably greater than the value of σ_p suggested by the history of the land is there any good reason to suppose σ_o to be greater than zero, and thus for there to be any correlation between P and G.

TABLE IV

MINIMUM RANGE TO BE EXPECTED FROM FIVE OBSERVATIONS DUE TO SAMPLING ERROR ALONE

Sampling error	10 per cent	5 per cent	1 per cent	0·1 per cent
±0·07	0·09	0·07	0·05	0·03
±0·15	0·19	0·15	0·10	0·06
±0·40	0·50	0·41	0·26	0·15

II. The relationship between soil pH and trunk girth

Three possible relationships were considered. The first was a linear relationship such as that detected by Goode (1954) and already alluded to in this paper. Such a relationship would be given by the expression :

$$g=h+kp \qquad (1)$$

where g and p represent girth and soil pH respectively and h and k are constants for a particular set of trees.

The second relationship was of the form :

$$g=hk^p \qquad (2)$$

the notation being as before. The reasons for considering this relationship were two-fold. Firstly girth might be related to soil pH as an exponential curve, and secondly it was desirable to study the relationship between soil pH and log girth, since girth data is most frequently handled in this form.

The third relationship was derived from a possible exponential relationship between growth and soil pH within the ranges studied, by regarding the growth stimulus as a parabolic function of soil pH, i.e., consistent with the conception of an optimum value of soil pH giving maximum growth. Such a relationship would be given by the expression :

$$g=hk^i \qquad (3)$$

where $i=a+bp+cp^2$, a, b, and c being constants and other notation as before.

Relationship (1) was tested by computing values of r_1, the correlation coefficient between girth and soil pH.

Relationship (2) was tested by converting the expression to the form :

$$\log g=\log h+p\ (\log k) \qquad (2a)$$

and computing r_2, the correlation coefficient between log girth and soil pH.

Relationship (3) was tested by converting the expression to the form :

$$\log g=\log h+\log k\ (a+bp+cp^2) \qquad (3a)$$

and computing r_3, the partial correlation coefficient between log girth and (soil pH)^2 for a fixed value of soil pH.

These values of r_1, r_2, and r_3 are given in Table V for each trial. In the same table is also given the standard error of pH after the elimination of treatment differences.

These figures suggest little difference between the first two relationships. There would be little

TABLE V

CORRELATION COEFFICIENTS BETWEEN SOIL PH AND GIRTH (r_1) ; SOIL PH AND LOG GIRTH (r_2) ; AND THE PARTIAL CORRELATION COEFFICIENT BETWEEN (SOIL PH)^2 AND LOG GIRTH FOR A FIXED PH (r_3)

Trial	Standard error of pH	r_1	r_2	r_3
1	±0·34	−0·4522*	−0·4539*	0·6523***
2	±0·53	−0·8180***	0·8270***	0·0244
3	±0·88	−0·5540**†	−0·3638	−0·1250
3a	±0·26	−0·4972	−0·5187	−0·1118
4	±0·91	−0·7258***†	−0·6973***	−0·1477
4a	±0·23	0·1847	−0·1858	0·3756
5a	±0·06	−0·0579	−0·0635	0·0238
5b	±0·07	−0·0645	−0·0714	0·0491
6	±0·33	−0·3323	−0·4015	−0·2064
7a	±0·20	−0·2858	−0·2914	−0·2313
7b	±0·20	−0·1882	−0·1989	−0·0736

* Significant at P=0·05 ; ** Significant at P=0·01 ; *** Significant at P=0·001 ; † Quoted from Goode (1954).

to gain from transforming the girth data to log girth, while, on the other hand, there would be little to lose if it were more convenient to use logarithms.

Except in the case of Trial 1, there seems no advantage in fitting the third relationship, with its increased amount of computation, and even in this case the curve of best fit as computed, is such that within the range of pH values encountered in the trial, its curvilinearity can scarcely be detected by eye when drawn. This should not be interpreted as implying that the true relationship is not curvilinear, with an optimum value of soil pH giving maximum growth ; such limited ranges of soil pH as were encountered in each trial would preclude the detection of any but very pronounced curves. Further, the fact that the linear correlations are, with only one exception, negative could be taken to imply that the range of soil pH encountered in each trial was, on the average, greater than the optimum value. Thus, from the data presented, the optimum soil pH for maximum growth would appear to be of the order of 5·5 units, or less.

The figures for standard error of observed pH confirm what has been suggested, that unless this standard error is sufficiently high there is no point in seeking a correlation.

Discussion

Many of the characteristics of a soil which cannot be readily recognized in the field but which may influence the growth of trees are associated, directly or indirectly, with the soil pH and it is therefore reasonable to expect soil pH to be associated with tree growth. It does not follow that pH itself affects growth ; it may merely reflect changes in the characteristics that do have that effect. In other words the relationship may be more statistical than biological. Since soil pH can be comparatively easily determined it constitutes a useful variate by which the precision of a trial may be increased through an analysis of covariance. Such a use of soil pH is conditional upon it being independent of the experimental treatments. This condition can be fulfilled by recording soil pH before applying the treatments. There would be little advantage if the soil pH was associated with a soil characteristic which was already being allowed for by the arrangement of the blocks in the trial design.

The most serious limitation of the technique is the magnitude of the sampling error of soil pH (σ_p) which demands a high variation of observed pH values, $\sqrt{(\sigma_o^2+\sigma_p^2)}$, before a correlation can be detected. A more accurate assessment of this sampling error, and the factors affecting it, than that available in the literature cited, or the limited assessment made in the course of this investigation, would greatly increase the value of the preliminary test suggested.

In some types of trial the experimental treatments will not affect the soil pH. In these cases it would still be an independent variate even when recorded after the application of treatments. This has the advantage that if the variation in a trial is found, after the application of such treatments, to be too great for the detection of treatment differences then it might be possible to reduce the variation by taking soil pH records on which adjustments could be based.

Acknowledgements

The writer is indebted to Dr. S. C. Pearce for his help and advice in the preparation of this paper, and to Mr. J. E. Goode for the benefit of his practical experience in the determination of soil pH.

Summary

The limitations of detecting a relationship between soil pH and trunk girth of apple trees, imposed by the sampling error of soil pH, are considered. Assessments of the sampling error under different conditions are made and a preliminary test of the likelihood of detecting a correlation between soil pH and trunk girth is suggested.

Three possible relationships between soil pH and trunk girth are studied.

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THE SELECTION AND USE OF A PANEL FOR TASTE SENSITIVITY TESTS WITH FRUIT

By G. H. FREEMAN

An account has been published of preliminary tasting trials with soft fruits (Way and Freeman, 1955), in which it was stated that, while the results obtained were of value, more information on the characters comprising flavour would be desirable. This paper describes the selection of a panel of people able to give an accurate description of these characters, and the way in which the panel has been used in practice. It is not intended here to give the results obtained by means of the panel, except in so far as they reflect on the selection of the panel or its use.

Selection

Purpose.—The selection of a panel must depend on the purpose for which it is used. The panel considered here was intended for use in describing flavour characters of soft and hard fruits.

It was desirable that panel members should be able

(1) to detect and describe primary flavours accurately,

(2) to discriminate between combinations of flavours in fruits and, as far as possible,

(3) to describe combinations of flavours when there were no added complications.

Each of these three requirements needed a different series of tests, and these are described below. An additional preliminary trial was necessary at the start of the selection work, but this will not be needed in future.

Preliminary trial.—The primary flavours which are present in fruit are sweetness, acidity, and bitterness, there being no appreciable salt content. The substances used for the selection of the panel were granulated sugar, sodium dihydrogen citrate, and quinine sulphate respectively. The first and third of these call for no comment, being in common use, but the second is more unusual ; it was chosen because citric acid is that most common in fruit and the buffered form would have a constant pH (approx. 3·9) for any concentration. In a preliminary trial with a few people the following concentrations of the substances were found to give good discrimination :

	Sugar	Sodium dihydrogen citrate	Quinine sulphate
	per cent	p.p.m.	p.p.m.
Strong	0·5	125	2·5
Weak	0·2	50	1·0

In general, stronger concentrations than these left too much after-taste, weaker ones were barely detectable, and those nearer together were too difficult to separate.

First series.—Using the primary flavours at the concentrations given above, a series of tests for the detection and description of these flavours was carried out. Seven bottles of liquid were prepared for the tasters to sample. Each assessor tasted from the bottles in turn, being permitted to go back to a previous bottle as frequently as desired. For the first few trials of this series the seven solutions were : (1) strong sweet, (2) strong acid, (3) strong bitter, (4) weak sweet, (5) weak acid, (6) weak bitter, (7) distilled water. However, after the tasters had had time to accustom themselves to the flavours, any one of the seven possibilities was allowed to occur an unspecified number of times. Two trials of the first type were sufficient for those people who took part in the preliminary trial, but four were found necessary for those who did not. The larger number is recommended when no preliminary trials are carried out.

After a dozen trials, of the first and second types together, lasting a week or more, it was evident which of the tasters were sensitive to these tests. The most sensitive were right, on an average, five or six times out of seven while others were consistently right four times or more. Some, including the writer, were often right no more than three times out of seven, which was plainly not good enough. The tasters were allowed complete freedom as to how they obtained their answers and the choice seemed to depend entirely on personal factors. Thus, just as successful results were obtained by those who tasted a sample of each liquid once only as by those who preferred to sip several times with distilled water between each sample.

Second series.—All who took part in the primary flavour tests then went on to the second series which lasted about the same length of time and whose object was to test powers of discrimination. In this series each person was offered portions of three apples, two alike and one different ; the difference was usually varietal, but sometimes the variety was the same but the stage of ripeness different. Each taster was given a piece of each of the three apples, peeled and cut up, and was then asked to indicate the one that was different. These trials were complicated by the possibility of identification by colour or texture ; further, two supposedly similar apples may differ appreciably, a point which tended to confuse the more sensitive tasters most. Despite the drawbacks this series seemed easier than the first, the better assessors almost all getting at least nine correct answers out of twelve.

Third series.—The two series of tests just described gave broadly similar results, though sometimes a taster who was good in one series was less good in the other. Those who were at least average in one series and better than average in the other then went on to a final series of tests for the description of combinations of flavours. To be included in the third, and final, series an assessor had to be right, on average, at least four times out of seven in the first series and to make not more than two errors in the second, or be right five or more times in the first and make at most three errors in the second. The most sensitive people satisfied the more stringent requirements in both series.

In the third series, tasters were asked to distinguish between the following combinations of flavours : weak acid+weak sweet, weak acid+strong sweet, strong acid+weak sweet, strong acid+strong sweet. (The same substances were used as in the first series, except that ' bitter ' was omitted as tending to confuse the issue.) As in the first series, initially one of each combination was present in a trial, but later any combination could occur any number of times. This was a very difficult test, and not even those who were almost infallible in the first series were as good here, correct answers not averaging much above two out of four, except for the very best. However, it did show that one or two of those on the borderline in the first two series should be excluded. One taster, who had not smoked for some years, started again just before this series and did very badly, but, on giving up smoking again, improved rapidly. Otherwise smoking appeared to have no effect on sensitivity. This third series completed the selection procedure. Out of 32 who started, ten were shown to be sensitive, and these formed the panel from which members were drawn for subsequent tasting trials.

Use

The panel, numbering from six to ten members for any particular trial, was used in 1955 to describe the flavour characters of different varieties of fruits, or of the same variety grown under different conditions of soil, cultural method or spray treatment, or differently stored. The panel was not told the types of difference that were present. All trials were conducted in the same way, there being no reason to suggest that different sorts of comparisons need different techniques.

Since the assessment of each sample required rather more detailed attention in these trials than in those described by Way and Freeman (*loc. cit.*) the number of samples was reduced to a maximum of four. As two samples would be too few for comparisons to have any meaning, there were thus always either three or four samples in a trial. Because there is a risk of taste fatigue with as many as four samples, this was the most that could be undertaken at a time.

Assessors were allowed to take the samples in any order, going back to previous samples as frequently as desired, and were asked to write down their opinions. Written opinions, giving more opportunity for careful consideration, were found preferable to verbal ones. The methods of recording opinions varied, some tasters describing the individual flavour constituents of each sample and others preferring a comparative basis, e.g., stating that A was sweeter than B and less acid. Descriptions of texture and other general remarks were also made.

Assessors have been allowed to go back to previous samples, but this procedure, though essential for considered judgements, has its drawbacks. There is an increased risk of taste fatigue ; further, especially with soft fruit where different fruits are likely each time, a second impression may be so different from the first as to raise considerable doubts in the assessor's mind as to the real flavour of the sample. When this happens it may be suggested that the method is faulty ; however, it may well be that the fruit is so variable that there is as much difference within samples as between samples. This occurred in more than one trial. Nevertheless it is better to risk the drawbacks consequent on the use of more than one assessment than to have inadequate replication.

From the results to date there has been no indication of unreliability of any of the panel members, although possibly some may have been particularly sensitive. The number of members on a panel should not be fewer than six. Even with a full panel of ten to draw from it has sometimes been difficult to find six for a specific trial, and in consequence it may be necessary to increase the numbers. Further members can readily be selected by the methods outlined above.

Acknowledgements

I am greatly indebted to all those who took part in the trials, whether or not they successfully passed the selection tests. I would also like to thank Miss E. Lawrence for the valuable assistance she gave in the recording of the tests.

Summary

The methods of selection and subsequent use of a panel for taste sensitivity tests with fruit are described. The selection procedure consisted of three series of trials, the first involving assessment of primary flavours, the second discrimination between fruits, and the third assessment of combinations of primary flavours. The panel selected on the basis of these trials and consisting of six to ten members on any one occasion has subsequently been used to describe the flavours of fruits differing either in respect of variety or of some soil, cultural, spraying, or storage factor.

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PLANT PHYSIOLOGY

INTERNODE GROWTH IN STOOLBED SHOOTS OF THE APPLE ROOTSTOCK CRAB C

By H. W. B. BARLOW and C. R. HANCOCK*

In the course of work on abscission carried out in 1948 it was observed that the diameter of defruited pedicels was markedly influenced by the application in lanolin of α-naphthaleneacetic acid or 2,4-dichlorophenoxyacetic acid. Later in that season, when young pedicels were not available, several experiments were carried out upon the formative effects of these substances using internodes of decapitated shoots. In the course of these experiments it was noted that the percentage increase in length of the immature internodes, as well as the diameter, was profoundly affected by decapitation ; further work suggested that the young leaves below the tip were playing some part in the elongation of these internodes.

As a result of these observations the experiments described in this paper were carried out, firstly, to ascertain to what extent the expanded leaves below the tip influence the extension of their own or neighbouring internodes, and secondly, to define more precisely the effect of the tip upon internode growth.

A parallel investigation is being made into the distribution of natural growth promoting and inhibiting substances in shoots of the type used here (preliminarily reported by Hancock and Barlow, 1953), and recently the two approaches to the problems of internode growth have been combined in an experiment in which the changes in growth substance distribution are being followed after applying treatments of the type described in this paper. The results of this and allied experiments will be published later.

Relatively little attention seems to have been paid to the factors controlling internode growth in unspecialized woody stems, though investigations have been made on ' long ' and ' short ' shoots of *Gingko* (Gunckel and Thimann, 1949 ; Gunckel, *et al.*, 1949) and *Cercidiphyllum* (Titman and Wetmore, 1955), and auxin studies have been undertaken in *Aesculus* and *Malus* by Avery, Burkholder and Creighton (1937) and in vegetative shoots (of the type used in these experiments) of a plum and an apple rootstock by Hatcher (1948) ; Champagnat (1949) briefly reports some experiments on *Sambucus nigra* which are referred to later.

Materials and methods

In the early work shoots on mature apple trees had been used, but this was discontinued owing to the limited period of the year over which they were obtainable and the small numbers of similar shoots available. All experiments now described were performed on shoots on a Crab C stoolbed, a convenient source of large numbers of vegetative shoots growing fairly uniformly from about May to September.

The details of the treatments applied to the shoots will be described for each experiment, but in general they consisted of the removal of one or a number of leaves, and the tip in various combinations. The ' tip ' comprised the unexpanded leaves and their internodes above an arbitrarily defined ' leaf 1 ' ; this leaf had just separated from the terminal cluster, was not quite fully unfolded, and had an internode below it of not less than 5 mm. The internode is given the same number as the leaf at its apical end, leaves and internodes No. 1 and below being numbered in basipetal order with positive numbers 1, 2, 3, *et seq.*, while those above are given negative numbers in acropetal succession −1, −2, −3, *et seq.* The sign is inserted where necessary to avoid confusion.

The length of the internodes was measured between leaf bases (or leaf scars) to the nearest millimetre, either with a short ruler or with specially constructed dial calipers with parallel jaws of perspex. Measurements were always made after internode growth was completed, and in some experiments during extension as well.

Results

(*a*) Effect of expanded leaves and the tip upon internodes 1 and 2.

The last of the experiments carried out on shoots in the orchard had indicated that if the tip

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and leaf 1 were removed there was a marked reduction in length of the first internode, but that it was necessary to cut off leaf 2 to influence the length of the second. A similar experiment was carried out on the stoolbed shoots ; the treatments and their effect on final internode length are presented in Table I. Measurements were made at the time of treatment in this experiment, and after 1, 2, 3, 4, 6, and 8 days. There was little influence of treatment during the first three days, but thereafter effects began to show up which foreshadowed those recorded on the 8th day.

TABLE I

LENGTH IN MM. OF INTERNODES 1 AND 2 ON 8TH DAY AFTER TREATMENT

Leaves removed	Tip			
	+	−	+	−
	Int. 1		Int. 2	
0	23·2	19·3	26·5	26·7
1	24·5	14·2	26·5	25·3
2	23·8	19·5	23·7	20·2
1 and 2	25·0	12·2	26·5	21·0

Removal of the tip has brought about a very marked reduction in the length of internode 1, but has had no effect on internode 2. This effect upon internode 1 is enhanced by removal of leaf 1, and a smaller effect is produced upon the second internode by removing leaf 2.

It was thought that the effect of removing leaf 2 upon the elongation of that internode may have been obscured by the presence of other leaves which might have contributed to its growth. Such leaves might be nearby, or possibly that leaf immediately below in the phyllotaxis, there being direct vascular connections between the two (Roach, 1938). To investigate these possibilities an experiment was performed in which, apart from undefoliated controls, all shoots had leaves 1, 3 to 9 inclusive, and 11 removed ; the tip, leaf 2, and leaf 10 (below leaf 2 on the phyllotaxis) were then removed in all combinations. It was found that the removal of leaf 10 had no effect upon either internode 1 or 2, and therefore the treatments which only differed in the presence or absence of this leaf have been averaged for the purposes of Table II, which thus shows the average of eight shoots except for the undefoliated controls, of which there were only four.

TABLE II

FINAL LENGTHS IN MM. OF INTERNODES 1 AND 2

Leaf 2	Tip			
	+	−	+	−
	Int. 1		Int. 2	
+	16·7	10·6	23·6	18·5
−	16·4	10·0	21·0	15·1
Untreated controls	21·8		24·0	

Removal of the nine (or ten) expanded leaves (1, 3 to 9, 11, and in half of the shoots No. 10) caused a pronounced reduction in the length of internode 1, but did not much affect the second internode. Removing the tip as well as these leaves had a drastic effect upon internode 1 and, in contrast to the previous experiment, quite a considerable one upon internode 2. The effect of removing the tip, and that of removing leaf 2, on the extension of internode 2, are more or less additive, the greatest effect being felt when both are removed together. The reductions in length, though not individually very large, are similar to those in subsequent experiments involving the removal of leaf 2.

In view of the marked effect of this large group of expanded leaves upon the growth of the first internode, it was desirable to determine whether it could be produced by smaller groups of leaves, and if so, which leaves were most important.

For this purpose three groups of four leaves were chosen, 1 to 4, 5 to 8, and 9 to 12 ; these

and the tip were removed in all combinations, making sixteen treatments. The final lengths (20 days after treatment), of internodes 1 and 2 are shown in Table III.

TABLE III

FINAL LENGTHS IN MM. OF INTERNODES 1 AND 2

Leaves	1–4	+				−			
	5–8	+		−		+		−	
	9–12	+	−	+	−	+	−	+	−
Internode 1	tip +	19	24	26	27	21	20	24	19
	tip −	18	19	15	14	11	10	11	11
Internode 2	tip +	27	23	26	24	24	28	23	24
	tip −	27	20	24	22	19	12	18	17

A very low value for internode 1 of the control shoots makes individual comparisons between certain treatments difficult, but the main effects are clear : (1) There was a large effect of removing the tip on the length of the first internode (average + tip, 22·5 mm., — tip, 13·6), and a smaller one on the second (+ tip, 24·9 mm., — tip, 19·9) ; (2) removing leaves 1 to 4 also affected the lengths of both internodes (internode 1, + leaves 1 to 4, 20·2 mm., — leaves 1 to 4, 16·0 ; internode 2, respectively 24·1 mm. and 20·6) ; (3) removing leaves 5 to 8 or 9 to 12 had no effect on either internode.

On breaking down these main effects into their component parts, it is clear that the effect of removing either the tip or leaves 1 to 4 is greatest when both are removed together ; on the other hand there seem to be no particular conditions under which the effect of removing the lower leaves shows up. Thus it would appear that removing the large group of leaves in the previous experiment affected internode growth mainly through the absence of the upper leaves, those below leaf 4 having relatively little influence.

This was confirmed by the results of another experiment (Table IV), where it will be seen that removing leaves below leaf 4 did not greatly add to the effect of taking off leaves 1 to 4.

TABLE IV

FINAL LENGTHS IN MM. OF INTERNODES 1 AND 2

Leaves removed	Tip			
	+	−	+	−
	Internode 1		Internode 2	
0	30	25	29	26
1 to 4	27	16	27	21
1 to 8	26	14	25	22
1 to 16	23	16	26	20
1 to base	23	16	28	23

In all experiments removal of the tip has resulted in a reduction in length of internode 1, which is intensified by removing leaves 1 to 4 (mainly, no doubt, due to the absence of leaf 1, as shown in Table I). The variable effect of removing the tip upon the second internode may have been due to the choice of a somewhat younger leaf 1 in some cases than in others, with a consequently younger second internode more likely to be affected by removing the tip.

In the experiment described in connection with Table III, internode lengths were measured 1, 3, 5, 7, 9, and 21 days after treatment, and in order to determine whether the differences in final lengths resulted from earlier cessation of extension after growing at a normal rate, or from a general slowing up of that rate, relative growth rates were calculated for each period according to the formula

$$\frac{\log_e l_1 - \log_e l_2}{t_2 - t_1}$$

where l_1 and l_2 are the internode lengths at times t_1 and t_2 the interval being in days. As no effect

was shown of removing leaves 5 to 8 or 9 to 12, these treatments have been averaged to show the effects of removal of leaves 1 to 4 and/or the tip upon the rates of growth of the first and second internodes. These rates are presented in Table V.

TABLE V

RELATIVE GROWTH RATES OF INTERNODES 1 AND 2 AT INTERVALS AFTER TREATMENT

		Tip							
		+		-		+		-	
	Leaves 1 to 4	+	−	+	−	+	−	+	-
		Internode 1				Internode 2			
Days after treatment	0–1	·21	·14	·09	·08	·14	·13	·12	·06
	1–3	·12	·13	·06	·02	·09	·08	·07	·01
	3–5	·11	·11	·07	·02	·06	·06	·08	·02
	5–7	·09	·08	·06	·02	·03	·02	·03	·01
	7–9	·05	·05	·04	·01	·01	·01	·01	0
	9–21	·01	·01	·01	·01	0	0	0	0

It is at once apparent that there is a very marked reduction in the growth rate of both internodes due to the removal of the tip, this being intensified by the removal of leaves 1–4. This reduced rate occurs during the first day and a lower rate is maintained throughout growth, which is continued for a similar period under all treatments. The shorter final length of a treated internode is thus due to a reduced rate of growth, rather than to an earlier complete cessation of growth.

It will be noticed that there is only a small effect of removing leaves 1 to 4 when the tip is present ; it was thought that this was probably because of the continued production of leaves from the tip, and attempts to remove these as they developed led to the series of experiments described in the next section.

(*b*) **Effect of the tip upon young internodes**

It has been shown in all the foregoing experiments that the tip has a major effect upon the growth of the first internode. In these experiments the tip consisted of all the young leaves as well as the actual apical meristem, and the question presented itself as to whether the reduction in internode length was due to the removal of the young leaves or of the apical meristem itself, or both. During 1952–1953 a number of experiments was carried out in this laboratory (Lockard, unpublished) in which varying numbers of small leaves from within the tip were removed ; indications were obtained that these small leaves were having a very marked effect upon the growth not only of internode 1 but also of those internodes which at the time of treatment were still within the tip and were not long enough to measure. It was found that up to 13 leaves could be dissected from the tip, but unfortunately when the majority of them were removed at once, the apex underwent considerable desiccation and frequently died. During 1954 two experiments were carried out, the first using a new technique in which young leaves were removed as soon as they reached a given stage, and the second a similar technique to that used by Lockard but only removing up to the seventh leaf above leaf 1.

In the first experiment leaves of three sizes were selected : leaf −4, a cylindrical organ about 1 cm. long, the edges of the lamina being tightly inrolled, and the petiole hardly distinguishable ; leaf+1, as before, the first leaf clearly separated from the terminal cluster, with a lamina 3–4 cms. long unfurled for most of its surface, and with a well developed petiole ; leaf+4, a definitely ' mature looking ' leaf, the lamina 6-7 cm. long, and dark green in colour. On each shoot one of these leaves was removed on the day the experiment began, and as successive leaves reached the same stage they also were removed. There were 13 main treatments (shown diagrammatically in Fig. 1, *a d*), consisting of an untreated control, and shoots with leaves −4, +1 or +4 removed as they developed, either 1, 4, 8 or 12 times. In addition, six further treatments were included (Fig. 1, *e* and *f*) in which four leaves were taken off at once, either when the majority of the leaves on the other treatments were removed for the fourth time, or for the twelfth time ; on both of these occasions the leaves which were *then* −4 to −1, +1 to +4, and +5 to +8, were removed. Each treatment was replicated five times.

In the second experiment leaves were removed at one time from various regions of the shoot between leaves +12, well down the shoot, to −6, up in the terminal cluster. Within this zone,

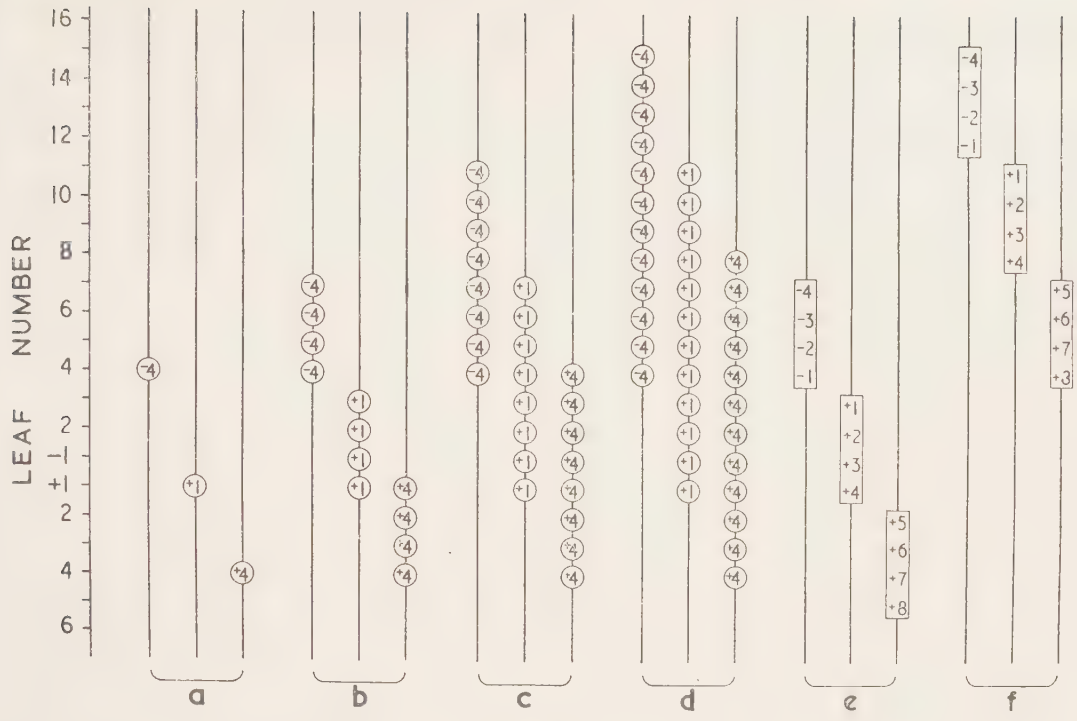

FIG. 1.

Diagrammatic representation of the treatments applied to Crab C shoots, referred to on page 92. Leaves were removed on (a) 1, (b) 4, (c) 8, or (d) 12 occasions, as they reached the developmental stages shown in the circles (−4, +1 or +4). The groups of four leaves shown in the rectangles were removed at one time, (e) when the last leaf was removed from the treatments shown in (b), or (f) when the last leaf was removed from (d).

groups of 4, 8, 12, or 16 leaves were taken off, these overlapping by two leaves thus the groups of four leaves were −6 to −3 inclusive, −4 to −1, −2 to +2, and so on down to +9 to +12 ; the groups of eight leaves were −6 to +2, −4 to +4, *et seq*. There were, in all, eight groups of 4 leaves, six of 8 leaves, four of 12 leaves, and two of 16 leaves, making 21 treatments with the undefoliated control ; there were five replicates.

In both experiments the shoots were harvested towards the end of the growing season but before the leaves had fallen. Lengths of all the internodes were obtained, and the lengths of any branches present at or near the treated region of the shoot, together with the number of secondary leaves either on these branches or in rosettes in the axils of the primary leaves. In addition, in the former of these two experiments the length and width of each primary leaf was recorded from the fourth leaf below the treated zone (+8) to the tip ; the product of length and width was used as an index of leaf area without further adjustment.

The results of the two experiments together will now be considered under three subheadings.

(i) *Effects of treatments upon internode length.*—Fig. 2 shows the effect upon internode length of removing the three leaf types −4(a), +1(b) and +4(c), once, 4, 8, or 12 times. Those treatments in which either leaf 1 or leaf 4 was removed once only were so similar to the controls that these three sets of values have been averaged together and used as a single control value. In the figure this has been taken as 100 for all positions on the stem and the lengths of corresponding internodes on the treated shoots expressed as a percentage of this value. To overcome some of the inherent variability in internode length within a given shoot, overlapping means of three were calculated ; this value (relative to the controls) has been plotted opposite the middle internode of each group of three, and the lines between the points have been dotted when two or more of the three leaf positions have been treated. Internode lengths of the controls thus appear as a horizontal line at 100 per cent, and a reduction resulting from treatment as a point below this level.

It has only been possible to use this percentage expression of the lengths up to internodes −16 to −18, as in all treatments there were some shoots in which the internodes above this region were becoming short due to growth slowing up towards the end of the season, while others continued to grow for a longer period.

It is at once evident that where leaf −4 or leaf +1 had been removed there was a reduction in

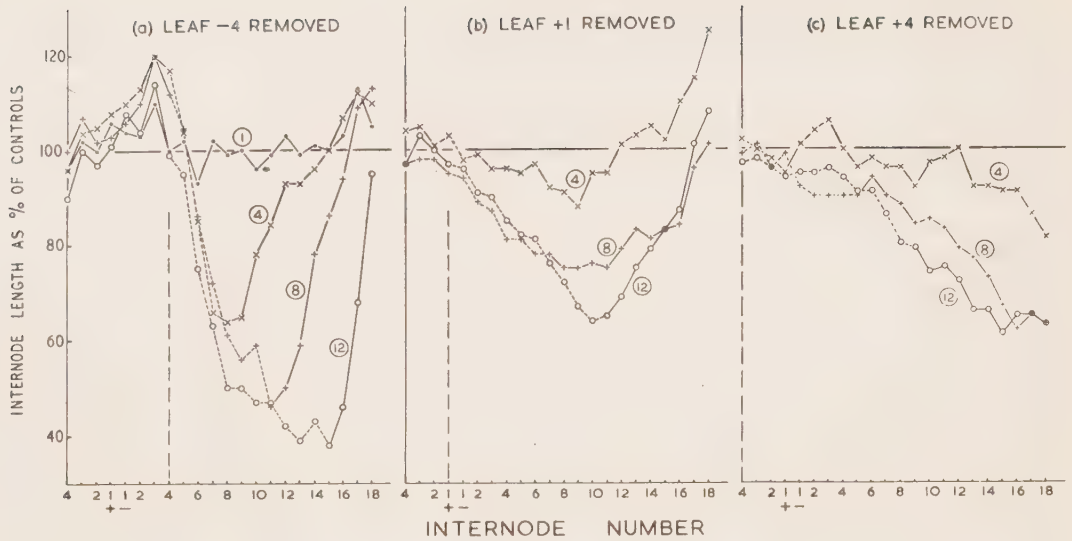

FIG. 2.

Effect on internode length of removing leaves at particular stages, 1 (·), 4 (×), 8 (+), or 12 (o) times, expressed as per cent of the controls. Stages were (a) leaf −4, (b) leaf+1, (c) leaf+4.
The defoliated zone is indicated by broken lines on the graphs, and the lowest leaf removed by the vertical dashes.

the length of internodes in the treated zone and above it, and that the degree of reduction, and the number of internodes affected, were both directly related to the number of leaves removed. The maximum effect, i.e., the shortest internode, was usually found immediately *above* the leaf last removed, after which there was a gradual recovery, control values being approached after 5–6 internodes had extended. Where leaf +4 was removed the nature of the effect was somewhat different : while the loss of four such leaves was unimportant, when 8 or 12 were removed there was a considerable reduction in the length of the internodes which appeared above the treated zone, and recovery did not occur during the remaining period of growth of the shoots.

One additional feature of Fig. 2(a) should be noted ; when leaf −4 was removed even once there was an *increase* in length of internodes −2, −3, and −4, with the maximum at −4 (though shown at −3 as an overlapping mean), this effect being increased when 4, 8, or 12 of these young leaves were removed. This result is considered further in the section on leaf areas.

In the additional treatments in this first experiment four leaves were removed at a time, and the results showed that the effect upon internode length was similar to that produced by the removal of four single leaves as they reached a given stage, although the lower internodes of the group were not so reduced since they had grown considerably during the period while the leaves were still present. The maximum effect occurred above the treated region and was very similar in both methods of leaf removal. For leaf −4, for example, removal on four successive occasions reduced the length to 64 per cent of the controls while removing the equivalent leaves as a group reduced it to 62 per cent.

The second experiment was an elaboration of the above treatments, in which groups of leaves were removed. Unfortunately the treatments were carried out late in the season and growth of the shoots soon slowed up, forming short internodes, so that recovery from the treatments could not be readily demonstrated. Nevertheless a number of features are worthy of note.

Fig. 3 illustrates the main results, internode length (overlapping means of 3) being plotted, with a control curve on each set a–d, since expression of the length relative to the controls resulted in anomalous values in the upper region of naturally very short internodes.

The removal of four leaves from within the tip markedly reduced internode length over the treated region, though, as previously noted, the maximum effect was immediately *above* the last defoliated internode. This effect became more pronounced as the region of defoliation was carried further up into the tip (Fig. 3 from c to a). When eight leaves were removed from the tip region the general picture was the same but with even more severe reductions in internode lengths (Fig. 3 a–c, +).

The effects produced by defoliation below the tip depended upon the ages of the leaves. Removing the younger ones, i.e., 1–4, reduced internode length over that region and for some distance above, an effect slightly increased by extending treatment to the 8th or 12th leaf below (Fig. 3d). This is in line with the results of previous experiments shown in Tables III and IV.

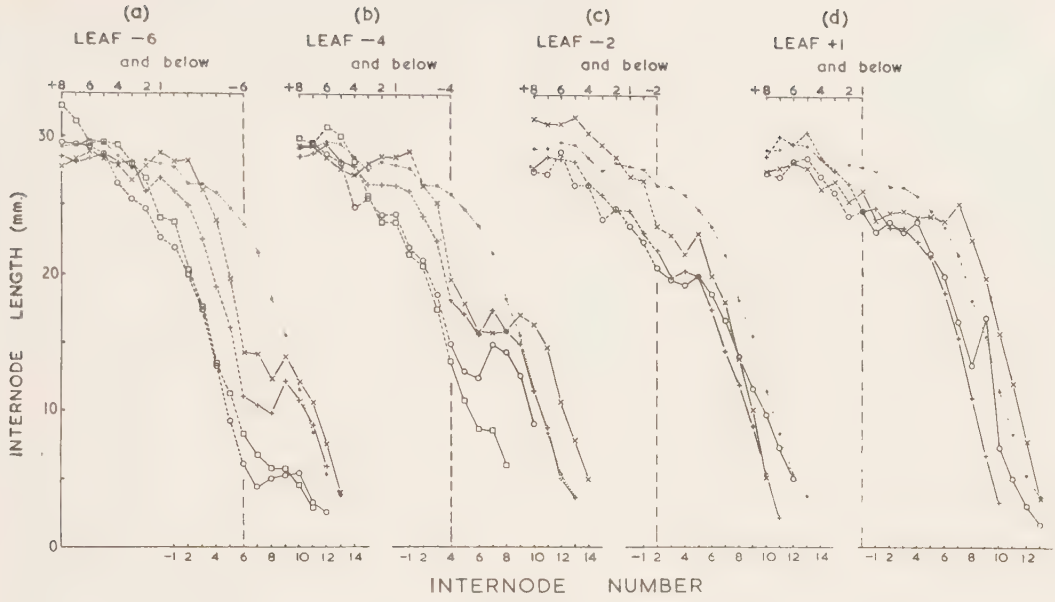

Fig. 3.

Effect on internode length of removing groups of 4 (×), 8 (+), 12 (o), or 16 (□), leaves on a single occasion from the following zones of the stem: (a) leaf −6 and below; (b) leaf −4 and below; (c) leaf −2 and below; (d) leaf +1 and below. The internode length of the controls is shown on each part of the figure as a dotted curve (·). The defoliated zone is indicated by broken lines on the graphs, and the uppermost leaf removed by the vertical dashes.

Removing groups of four leaves below leaf +3 had no effect on internode length anywhere, but when six or more such leaves were removed there was a general depression of internode growth over much of the shoot; the shoots stopped growing before recovery occurred.

Those treatments with groups of 12 or 16 leaves covered a region which included a considerable number of small leaves as well as mature ones; loss of the former caused a reduction in internode length over the treated region, with a tendency to recover above it. Superimposed on this was the general reduction in internode growth associated with removal of the lower leaves, operating against the recovery of internode length. These treatments thus exerted a drastic effect, as shown by the lowest two curves in Fig. 3 a and b (o and □).

(ii) *Effects of treatments upon branching.*—In the defoliated region of the shoot the axillary buds sometimes developed. This growth began very early, for example, where leaf −4 was removed, the axillary bud had grown out as a pair of very small leaves adpressed against the stem by the time the node had reached the leaf 1 position, i.e., five plastochrons later, or about ten days in mid-season. Subsequently the buds developed into branches or rosettes of leaves, and the lengths of these branches and the number of leaves produced in the former of these experiments are shown diagrammatically in Fig. 4.

Secondary leaves grew out in all cases where primary leaves were removed from either the −4 or +1 position, but never where leaf +4 was taken off. The longest branches and the maximum number of leaves were found at the node from which the lowest leaf of a group had been removed, or at the one next above. Axillary buds developed at all defoliated nodes, growth decreasing as the leafy tip was approached, and where leaf −4 was removed secondary growth also occurred for at least five nodes below the treated zone. The amount of such growth appeared to increase with the number of leaves removed, although taking off leaf −4 twelve times resulted in shorter branches than removing it eight times.

As already mentioned the second of these two experiments was late in the season, and growth ceased before lateral branches had extended. Rosettes of leaves had formed however, and the total number per treatment, and their distribution, are recorded in Table VI for the twelve treatments which caused their development. In the remaining nine ineffective treatments no leaves above +1 were removed, and in none of the other treatments did secondary leaves occur below node number +2, confirming the results of the previous experiment, where removing leaf −4 did not stimulate growth of axillary buds. Unlike that experiment, however, in this one secondary leaves occasionally grew out *above* the defoliated zone, but in the two cases where this occurred (the 4th and 6th columns from the left in Table VI) the growth in that region was very limited.

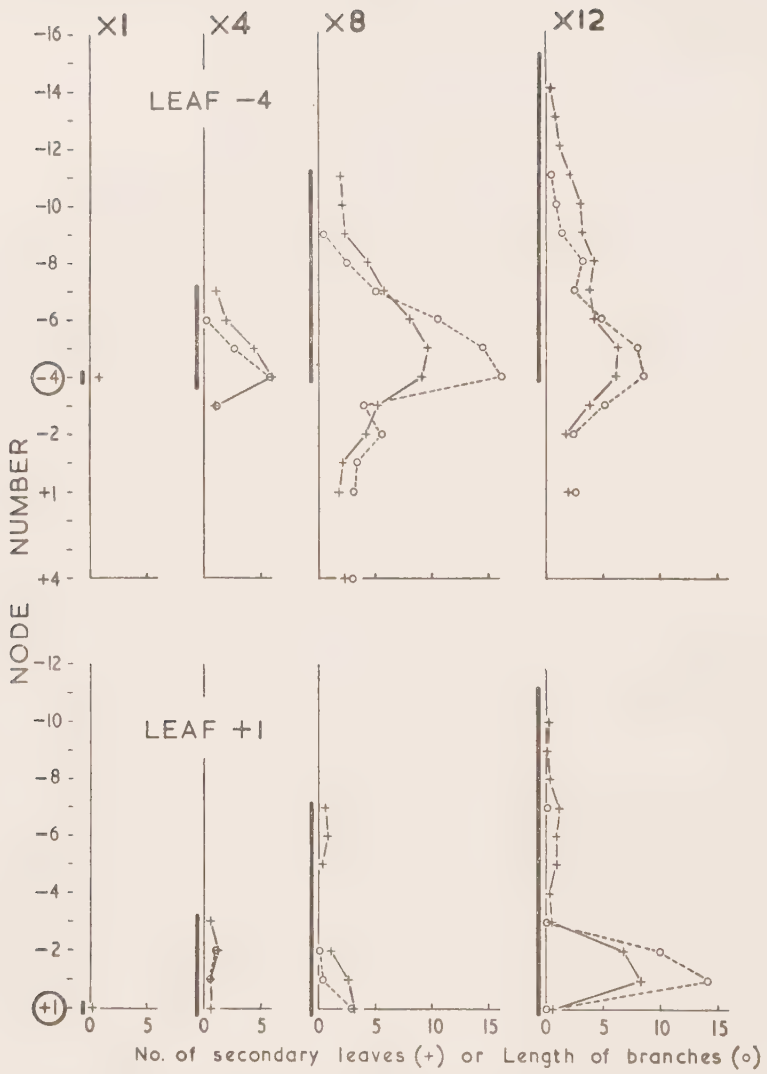

FIG. 4.

Effect on development of axillary buds, as shown by number of secondary leaves produced (+solid lines), and length of branches (o broken lines), of removing leaf −4 (upper diagrams), or leaf +1 (lower diagrams), 1, 4, 8, or 12 times. Where the value is zero the symbol has been omitted.
The heavy vertical line to the left of the ordinate shows the region which was defoliated.

TABLE VI

AVERAGE NUMBER OF SECONDARY LEAVES PER SHOOT AND THE PRIMARY NODE NUMBERS AT WHICH THEY OCCURRED

Total number of primary leaves removed	4				8			12			16	
Position of primary leaves removed	−6 to −3	−4 to −1	−2 to +2	+1 to +4	−6 to +2	−4 to +4	−2 to +6	−6 to +6	−4 to +8	−2 to +10	−6 to +10	−4 to +12
Number of secondary leaves	12·0	20·5	2·5	5·5	13·5	22·0	3·5	17·5	13·5	4·5	23·0	7·0
Position of primary nodes with secondary leaves	−6 to −2	−4 to +1	−2 and −1	−3 to +2	−5 to +2	−5 to +2	−2 to +1	−5 to +2	−4 to +1	−2 and −1	−5 to +1	−4 to +1

Both experiments, however, clearly demonstrate the importance of the very young leaves in the tip in controlling axillary bud growth.

(iii) *Effects of treatments upon leaf area.*—Examination of the leaf size records showed that there was considerable variation from shoot to shoot, some tending to have small leaves throughout and some large. To make it easier to compare the treatment effects, therefore, the four mature leaves (+5 to +8) below the lowest treated zone were taken to characterize the shoot, and the sizes of the leaves above them were expressed as a percentage of the average of these four. Table VII shows the relative sizes of leaves immediately below and above the treated zone, where this was more than a single leaf. As an indication of the natural variations in size along the shoot the averages of corresponding leaves on the control shoots are shown in brackets.

TABLE VII

RELATIVE SIZES OF LEAVES IMMEDIATELY BELOW AND ABOVE THE TREATED ZONE, AND, IN BRACKETS, AT CORRESPONDING SITES ON THE CONTROL SHOOTS

Position of leaf removed 4, 8, or 12 times	Below treated zone	Above treated zone
−4	120 (106)	98 (98)
+1	114 (105)	130 (103)
+4	95* (97)*	115 (103)

* These values are for leaf +5, which has itself been included in the average of +5 to +8 to which the other leaf sizes have been related.

It will be seen that removing leaf −4 brought about an enlargement of the leaf immediately below it, but had little effect on the leaves above the defoliated zone. Similarly, removing leaf +1 stimulates an increase in size of the leaf below, though to a lesser extent, but, in contrast to leaf −4, there is a large increase in size of the leaf above the treated region. Removing leaf +4 has no effect on the leaf below it (it being almost fully expanded at the time of treatment) and has a smaller stimulatory effect on the first leaf left above than had removal of leaf +1.

Discussion

Stoolbed shoots of Crab C, during the major part of their growth, have four or five easily measured internodes (more than 5 mm. long) which are still elongating. Of these, the lower two have completed most of their growth in length, and have a low growth rate ; it is thus unlikely that their final lengths can be greatly affected by any treatment. In the case of the upper two, however, less than half their total growth has been completed and their growth rates are high, so that it is probable that any reduction in the supply of substances required for their extension will have a marked effect upon the final length achieved. The internal factors which can be considered as controlling growth are of two types—growth substances and food factors. The former may be promoters of growth, which are generally considered as being produced in the apical regions, and which, at least in the vegetative shoot, move in a strictly polar manner (for examples, see references given by Gregory and Hancock, 1955) or they may be inhibitors, about which few generalizations can yet be made. Food factors include the inorganic components of material supplied from the roots, and elaborated organic material from the photosynthetically active leaves, and possibly elsewhere in the plant, and may be visualized as arriving at the extending internodes from below. The experiments described in this paper have examined the ' tip ' and the leaf at various positions on the shoot, as possible sources of one or the other type of substance needed for internode extension ; the influence of a given part has been assessed by observing the effect of removing it upon internode growth.

Removal of the tip has been shown to have a very marked effect on the extension of the first internode, an effect which is enhanced if the young leaves below the tip are also removed. Decapitation by itself affects the second internode much less, and often its length is only reduced when the leaves in this region are also removed.

Such results are compatible with the view that the major source of auxin is the tip, but that it is also supplied by the young leaves. The removal of the tip would therefore leave internode 1 with only a small supply of auxin from its own leaf, so that its extension would be much less than in the intact shoot. (It should be mentioned that Champagnat (1949) working on *Sambucus* found very little effect of removing the tip on the growth of the internodes below ; a comparison between apple and *Sambucus* might thus be valuable.) The additional removal of leaf 1 would

deprive the internode of even that source of auxin, so that within a few hours all free auxin would have moved out of this region of the stem (Gregory and Hancock, 1955), and growth would cease. The second internode on the other hand will be supplied with auxin by two leaves even after decapitating the shoot, and as this internode has less growth to complete, this supply is probably adequate to achieve a normal final length ; if these leaves are also removed, however, then, as in the case of internode 1, the auxin level will quickly fall, and growth will stop. In fact, growth did not cease abruptly, as seen from Table V, but whether the low rate which was maintained was due to a slow production of auxin in the internode itself, or to activity in the axillary buds, or even in the stipules left attached to the petiole stumps, was not ascertained.

This explanation in terms of the tip as the major source, and the young leaves as minor sources, of auxin is in accord with some findings reported in the literature, but not with others. For example, the terminal cluster and/or young leaves have been found to be rich sources of auxin by Avery *et al.* (1937) in *Aesculus* and *Malus*, Jacobs (1952) in *Coleus*, and Hancock and Barlow (1953) in apple. On the other hand, Hatcher (1948) in plum and apple, Champagnat (1949) in *Sambucus*, Gunckel and Thimann (1949) in *Gingko*, and Titman and Wetmore (1955) in *Cercidiphyllum*, all consider that auxin production is centred in the elongating stem itself, while Smith (1945) in Guayule found the highest auxin yield on a weight basis in the mature leaves, with very little in the terminal bud or the stem. Some of these differences may possibly be resolved by relating auxin yields to the amount of tissue involved, rather than to a length of stem, or to a unit such as a leaf or an internode ; for instance Delisle (1937), referring to diffusible auxin from growing leaves of *Aster*, suggests that ' the amount of auxin diffusing varies approximately inversely with the size and age of the leaf ', while Goodwin (1937) working with two species of *Solidago*, writes, ' the amount of auxin per unit of fresh leaf weight in each species is more or less inversely proportional to the weight of the leaf, indicating that auxin production may reach a maximum in the youngest leaf primordia '.

Apart from such difficulties, confusion may also arise by failure to distinguish between the *production* of auxin and its *release* from a given site, to which it may have been moved before estimation. The further problem of precursors being formed in the young leaves rather than auxin itself, offers another interpretation (Larsen, 1951, for example, p. 186 *et seq.*), which will not be attempted here.

The removal of a number of leaves from the tip region, either at one time, or as they reach a given stage, produces certain effects on the developing internodes which are not readily explained by the commonly held views on auxin production and transport. The first of these is the reduction in length of the internodes *above* the treated zone, which in the case of removing leaf −4 or +1 is roughly proportional to the number of leaves removed, achieving the greatest reduction just above the defoliated zone, followed by a gradual recovery over the next 4 or 5 distal internodes.

Such a result indicates that in the extreme tip region the influence of the leaf is felt more in an acropetal than a basipetal direction. As it is improbable that the small leaves removed here would have been contributing food factors for internode extension, their importance is more likely to be as sources of growth substance. Should this be so, it is surprising that the maximum effect of removing these leaves should occur immediately *above* the treated region, and that normal extension should not be achieved immediately leaves are allowed to remain. An hypothesis to account for these facts would probably need to invoke apolar transport of growth promoter, or a complex of inhibitors, precursors, and so on, which would not be justified until considerably more is known about auxin production and movement in these very young organs.

It is important to note here that the effects of removing the very young leaves upon the development of the axillary buds would comply with the more orthodox view of bud inhibition by a growth substance transported basipetally (Thimann, 1937). Removing the young leaves is considered as reducing the supply of auxin and so releasing the axillary buds from inhibition, more or less in proportion to the number of leaves removed. Loss of bud inhibition very rarely occurs above the treated zone—probably never in vigorously expanding tips—although it may extend below the leafless part of the stem. Removal of leaf +4, which is not a rich source of auxin, did not result in development of the axillary buds.

It should be pointed out that when apical dominance is removed in such a treatment as pruning, a shoot is usually cut back to a dormant lateral bud, which is stimulated to grow out into a branch. In contrast, the removal of the very young leaves described in the present paper resulted in the outgrowth in the tip region of rudimentary buds which had never entered a dormant stage with bud scales, etc. It is of interest to note that a similar kind of growth often occurs where very small caterpillars have damaged the leaves within the terminal cluster. Delisle (1937) found a similar effect of removing young leaves on branching in *Aster*.

The second effect which is difficult to explain is the *increased* growth of the internodes immediately *below* the zone from which leaf −4 was removed (Fig. 2a). It is possible that the absence of such

young leaves frees food material for use by the remaining organs, so that internodes −3 and −4, and leaf −3 utilize this extra allowance, and grow larger than they would have done in the presence of all leaves on the intact shoot. The leaves *above* the defoliated zone, however, were apparently unable to benefit.

A similar, though smaller, effect on leaf size was observed in leaf +2 when leaf +1 was removed four or more times (Table VII), but as the internode is older there is probably less chance for it to benefit so much as the younger internode from extra food material. Furthermore in this treatment the leaf *above* the treated zone was larger than normal, suggesting that the leaves in the rapidly expanding phase between −3 and −1 compete strongly for available food material, although the increase in leaf size was not by any means always reflected in internode length. Jacobs and Bullwinkel (1953) found similar effects in *Coleus* and make interesting use of the concept of ' compensatory growth '. They suggest that a treatment which leads to compensatory growth of this kind—an increase in leaf area and internode length—acts primarily on the leaf, which in turn then influences the stem below it. They, too, found that removing the young leaves reduced elongation in the defoliated zone.

The effects on internode growth of removing the older leaves from a shoot may be interpreted in terms of food supply. It has been shown that when a considerable number of lower leaves are removed there is a marked reduction in the extension of the young internodes for a long time. Since it is known that the lower leaves produce very little (if any) auxin (Hancock and Barlow, 1953), and also that auxin transport in this part of the stem is strictly polar, it can only be assumed that the smaller photosynthetic surface has led to a reduced supply of food materials reaching the extending internodes. Titman and Wetmore (1955, p. 371) remark in connection with long shoots of *Cercidiphyllum* : ' The continued removal of the photosynthetic areas, as the developing leaves are excised, may also be a factor in retarding shoot elongation '. They equate this effect with the term ' vigor ' used by Gunckel *et al.* (1949) in connection with *Ginkgo*. Such an effect would no doubt continue to be felt until sufficient leaves had been developed above the defoliated zone to make the loss in area small in proportion to the total, or until leaves comparable to those removed have become senescent or inefficient in photosynthesis.

The effects of removing the young leaves upon the internodes in their immediate vicinity have already been considered, but as the shoot develops, so each leafless region will eventually come into a position where the leaves if present would have been contributing ' food factors ' to internodes above ; when this occurs there should be a secondary effect of loss of these leaves upon the new group of internodes as well as the primary one upon the internodes near the treated zone. This effect could not be detected in these experiments when very young leaves had been removed, because they were carried out too late in the year for these regions ever to reach the position of major contributors of food material. In the case of removing leaf +1, however, the secondary effect would occur sooner, and it is possible that such may be the explanation of the very extended effect of removing these leaves upon the internode growth above the treated zone (Fig. 2b).

The experiments reported in this paper deal only with the effects on internode extension of relatively crude ' surgical ' treatments ; attempts to replace the influence of the excised organ with exogenous supplies of either growth substances or food materials have not been successful, though instances of the former are described in the literature. Other effects of such treatments (for instance on leaf area, and on the rate of development of new leaves) are being investigated and the effect of decapitation and leaf removal on the status of growth promoting and inhibiting substances in the internode is also being determined.

It is to be hoped that studies of this kind will provide information on some of the factors controlling internode extension in woody shoots, which may ultimately assist in the interpretation of some of the aspects of tree form, such as variation in growth during a season, the degree and position of branching, or the formation of the ' spur ' and other types of shoots.

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Although it is not possible for individual acknowledgements to be made to the many people who have assisted in the often laborious task of recording these experiments, the authors would like to thank Mr. P. R. Wycherley (in 1950), Mr. B. D. Harrison, and Miss G. B. Brown (in 1951), who as Temporary Recorders attached to the Physiology Section, carried out much of the work on the experiments in those years.

Summary

Experiments on vegetative shoots are described in which various parts were excised in order to assess their influence on elongation of the internodes.

Removal of the tip (the terminal cluster of very small leaves enclosing the apical meristem) reduced the extension of the first internode below, without greatly affecting the second.

Removing the leaves below the tip (1 and 2, or 1 to 4 inclusive) led to further restriction in the lengths of these two internodes, but the effect was not much increased by taking off additional leaves.

The reduction in final internode length is the result of a lower growth rate after treatment rather than an earlier cessation of growth.

The effect of the tip was analysed by removing the very small leaves therein, either as they attained a particular stage of development, or in groups at one time. Removal, by either method, profoundly affected the final lengths of the internodes nearby, *increasing* the length of the internode just *below* the treated zone, and *decreasing* the lengths of those *in*, and just *above* it.

Development of the axillary buds was brought about by excising the small leaves, to an extent more or less proportional to the number of leaves removed. Certain defoliation treatments affected the size of the leaves below and/or above the treated zone.

The results are discussed in terms of the supply of growth substances and food materials to the extending internodes.

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EXPERIMENTAL APPROACH TO THE DEVELOPMENT OF AN ADEQUATE TECHNIQUE FOR WATER CULTURE OF APPLES

By B. D. BOLAS and H. C. RUCK*

Although a large variety of herbaceous plants have been grown with complete success in water culture, efforts to apply this technique to woody perennials have been less successful (Colby, 1933), and various workers have encountered difficulties in growing the apple under such conditions (Barker, 1920 ; Harris, 1929 ; Dunn and Roberts, 1954). The present paper reports the development of a technique for growing some of the Malling rootstocks in culture solution. As it has been generally observed that the roots of apples in water culture are very susceptible to fungal and bacterial attack, particular attention was paid to this factor, and the effect upon it of pH, aeration, and temperature of the nutrient solution.

Interaction of rootstock, pH, and aeration

The general methods of culture, including the constitution of the solution, are described in detail elsewhere (Bird and Ruck, in press), and the following findings appear to be well established from their experiments : (1) rootstocks differ markedly in their susceptibility to attack by micro-organisms, M.II and M.IX being less resistant than M.XVI ; (2) high acidity (low pH) of the nutrient solution reduces attack in all cases, but when the pH is lower than 5·5 the growth of the plants is also reduced ; (3) adequate aeration is essential. As controls in these experiments the same rootstocks were grown in sand in 10-inch pots, watered with the same nutrient solution at pH 5·5, and also in a mixture of soil and John Innes compost (pH 6·5) top dressed at fortnightly intervals with dried blood. Neither in sand nor in soil were any plants lost due to root damage by micro-organisms.

Infection of the roots in water culture did not appear under either aerated or non-aerated conditions until some six weeks after the beginning of the experiment, but after this infection rapidly increased, the rate of increase being dependent on both variety and treatment. Among the replicates of M.XVI, some individuals growing in solution at pH 5·5 escaped infection, and these grew as well as those in sand culture.

Two possible explanations were envisaged, namely : (1) that during the course of the experiment some antibiotic factor accumulated in the culture solution, and that its production differed in the three rootstock varieties ; (2) that, as the season advanced, the rising temperatures favoured attack by micro-organisms in the solution.

The effect of antibiotics in the nutrient solution

Much work has been done on the control of plant diseases by antibiotics (Anderson and Gottlieb, 1952), and it was decided to test some of them under these conditions. The fungus attacking the roots was identified as a species of *Pythium*. This fungus is known to be sensitive to patulin (Anslow *et al.*, 1943), consequently this antibiotic was selected first.

Aerated cultures in 5-litre beakers were set up in the greenhouse and maintained at pH 4·0 in one series and pH 5·5 in another. M.II rooted shoots were established in the solutions, and then patulin was added to make final concentrations of 1 and 5 p.p.m. respectively in each of two sets of cultures. Within a week injurious effects were observed in the 5 p.p.m. solution, and when the experiment was terminated three weeks later, in all cases patulin had reduced growth and the number of survivors.

A similar experiment was carried out with sulphanilamide on M.IX, at final concentrations of 50, 100, 250, and 1,000 p.p.m. Within twelve days, black marginal areas had appeared on the leaves of the 1,000 p.p.m. treatment, although there were no signs of root damage. After another month, root growth was reduced in all concentrations as compared with such of the controls as had not become infected, although in no treatment was bacterial slime present on the roots.

Other known antibiotics were not investigated, but a nutrient solution, in which M.XVI rootstocks had grown healthily the previous year, was tested for the presence of a possible antibiotic by adjusting its nutrient level and pH to the standard, and growing further rootstocks in it. Rapid attack by micro organisms showed that no permanent benefit had been conferred on the solution by the resistant stocks.

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The effect of temperature of the nutrient solution

In the experiments of Bird and Ruck very few deaths of any of the plants grown in water culture occurred in April and May, the first two months of the experiments, but later in the season there was a rapid increase in death rate. This suggested that the temperature of the culture solution can affect either host susceptibility or the multiplication rate of the micro-organisms.

To test this, M.IX rootstocks were grown in 30-gallon tanks in April 1955, one kept at 8°–14° C., a second at 20°–25° C. throughout, and a third at an uncontrolled temperature which ranged from 8°–25° C. during the experimental period. All solutions were aerated. By 25th July the plants kept in the cooled solution showed two dead out of a total of eleven, whereas in both the uncontrolled and the heated solutions only two out of 15 plants survived. At this time, four surviving plants from the cold tank were transferred to the warm tank and the total number made up to 15 with new plants. By 8th August all the plants transferred to the heated tank were dead, while in the cold tank all plants remained healthy. Low temperature of the solution thus greatly reduced the death rate, but did not completely prevent fungal attack.

In a further experiment begun in April 1955, M.IX rootstocks were grown in water culture in 12-inch earthenware pots, sealed at the bottom and coated internally with liquid bitumen, and sunk in the soil. The cultures were aerated. On 8th August all plants were healthy, with very little infection of the roots.

The effect of immersion of the stem of the cutting in the solution

In the earlier experiments of Bird and Ruck carried out in 1954, the stem was immersed in the culture solution, and it was thought that this might have been a factor contributing to the early death of the plants. In 1955, precautions were therefore taken to ensure that the stem was never so immersed, by rooting the plants in compost before transfer to the culture solutions. In the experiments on the temperature effects of the culture solution, the plants had all been treated in this way, and unfortunately there were thus no controls in which the stems were immersed from the start. It is, therefore, not possible to separate the effects of high temperature of the solution and of immersion of the stem, and further work on this point needs to be done.

Discussion

A method has been devised for growing Malling rootstocks in solution. Adequate aeration of the culture solution is essential, and it appears that the temperature of the solution must be maintained below 25° C. if infection of the roots is to be avoided. Temperature may play a part in two ways : by encouraging growth of the micro-organisms, and by direct effect on the growth-rate of the roots. Nelson and Tukey (1956) postulated a direct effect of temperature on the growth of roots of Malling rootstocks, and Nightingale (1935) has shown that root growth in sand culture is poor at temperatures of 28°–30° C. On the other hand, in experiments with rootstocks grown in spray culture (Roach, 1952) growth was excellent and the roots remained healthy although temperatures of 29°–30° C. were reached. It would appear, therefore, that the action of high temperature is mainly indirect, and that the detrimental effect is primarily due to rapid multiplication of micro-organisms in the culture solution. The effect of stem immersion remains obscure and further work needs to be done to analyse this. When the conditions of culture described are adhered to, pH of the solution appears to be unimportant.

Summary

Experiments are described which investigated the cause of death of apple rootstocks in solution culture ; these led to the development of a successful method for growing them under these conditions.

Temperature of the nutrient solution is an important factor.

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A METHOD FOR THE RAPID DETERMINATION OF LEAF AREAS IN THE FIELD

By G. H. FREEMAN and B. D. BOLAS*

The measurement of leaf area in small laboratory experiments, although often tedious, is not a limiting factor in the planning of experimental work, and several methods for the determination of leaf areas under such conditions have been used successfully. Gregory (1921) used a gonometric method, Gerdel and Salter (1928) a photoelectric method and Bolas and Melville (1933) a visual photometric method, all of which were reasonably adequate.

The problem is very different when growth analysis of field crops is attempted and measurements have to be made on relatively enormous numbers of leaves without damage to the plant. Some reduction in the labour can be made by an estimate of the area of what it is hoped are representative leaf samples but, even so, many field experiments are of necessity limited by the speed and accuracy with which leaf areas can be determined. Numerous attempts have been made to evolve a reasonably good method, e.g., Vyvyan and Evans (1932), Goodall (1947), Ruck and Bolas (1956), and Boynton and Harris (1950), the last of whom also consider sampling methods.

This paper describes a method which on a basis of speed, simplicity, and accuracy appears to have notable advantages over those at present in use. It has been submitted to a critical statistical analysis, details of which are given below.

Method

The technique described here is based on the simple principles illustrated in Fig. 1. The leaf is assumed to be an ellipse, and this assumption appears perfectly satisfactory for the present purpose. Leaves have varying shapes, but all apple leaves are similar to that shown in Fig. 1, from which it can be seen that the area of the ellipse closely approximates to that of the leaf. The chief differences between particular leaves are likely to lie in the amount of asymmetry and in the length of the leaf tip, but these can both be allowed for in practice.

Since the leaf is assumed to be an ellipse its area can be determined by a knowledge of its main axes. The major axis of the ellipse lies along the mid-rib of the leaf and the minor axis is at right angles to this at the widest part of the leaf, the semi-axes being a and b respectively. If the leaf is so placed that its base touches the x-axis and one side touches the y-axis of a system of rectangular cartesian co-ordinates then the second side of the leaf touches a line parallel to the y-axis in the point P whose co-ordinates are $(2b, a)$. Since the area of the ellipse is $\pi\ ab$, the product of the co-ordinates of P bears a constant relation to this area. If, therefore, a grid can be arranged so that a leaf will touch the axes of co-ordinates and the point P can be found, then, by a suitable graduation, the area can be read off directly.

The grid is constructed as follows : points are plotted on a graph with integral co-ordinates and the products of these co-ordinates written at the points; in order that an area of $\pi\ ab$ shall be shown at a point whose co-ordinates are $(2b, a)$ the area of the graph is reduced in the ratio $2/\pi$, and the linear dimensions of the grid are thus $\sqrt{2/\pi}$ of those on the graph. Such a grid is shown actual size in Fig. 2, the numbers being areas in square centimetres of ellipses touching the axes and the point P ; the area of the leaf shown would be estimated as 29 sq. cm. (In Fig. 2 the numbers on the full lines are exact, those on the dotted lines alternately 0·25 sq. cm. too big or too small, but this inaccuracy is unimportant.)

Assay

In order to test the method two trials were conducted, the main one in the laboratory and a subsidiary one in the field. In the laboratory trial the areas of prints of twenty leaves of known area were determined by means of the grid from each of the following twelve sets of plants :

In soil : unworked rootstocks—3423, M.IX (two sets), MM.109, Crab C, M.XVI ;
worked trees —Cox/M.IX, Cox/M.XVI.
In water culture : unworked rootstocks—M.IX, M.XVI ;
worked trees —Cox/M.IX, Cox/M.XVI.

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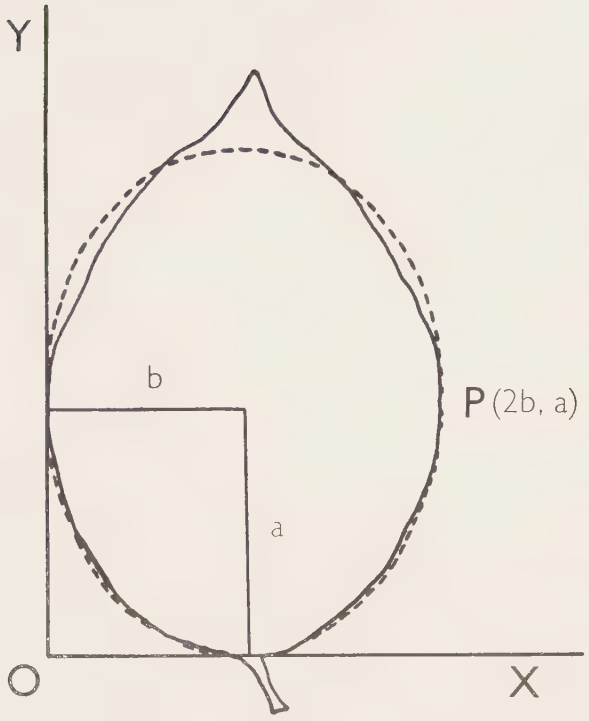

FIG. 1.

Representation of an apple leaf and an ellipse with the same axes.

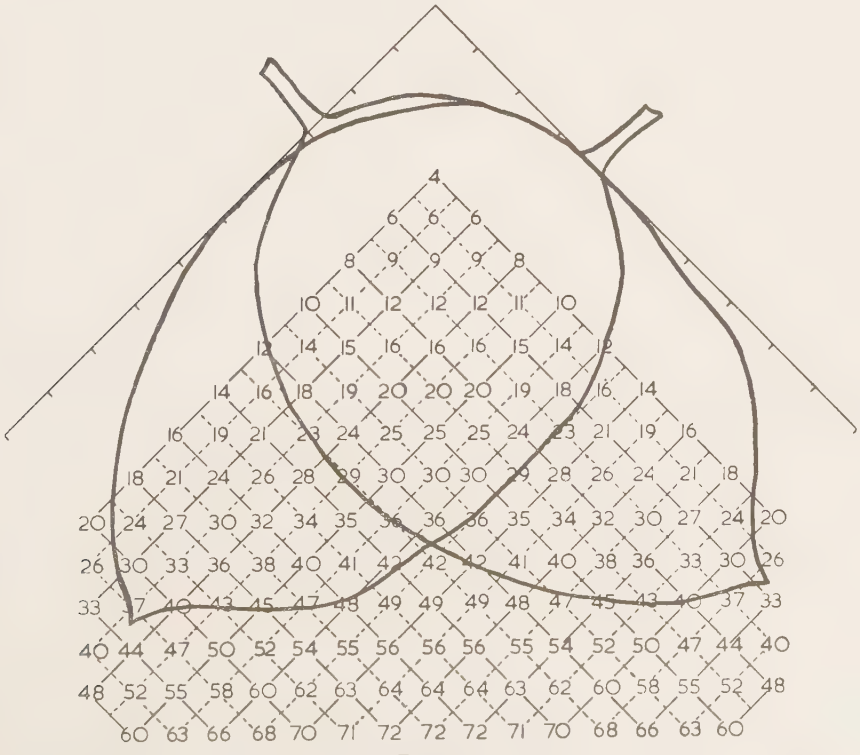

FIG. 2.

Grid for measuring leaf areas (actual size), showing typical leaf in two positions.

The determinations were made by four observers, each of whom determined the area twice, by having the point P either on the right or on the left of the leaf.

In the field trial the areas of each leaf on a Crab C plant were determined by the grid method, and by measuring the length and breadth of the leaf and calculating their cross-product, the actual leaf areas being subsequently determined. Three observers were concerned here, all of them with considerable experience of the cross-product method ; two of the three had used the grid in the laboratory trial, and one had never used it.

Since, in practice, the method is intended to be used to give a direct reading of leaf area, the following points need particular attention. First, there must be no differences between observers. Secondly, the variation due to the use of this method should be negligible compared with the variation between leaves ; this is the most important consideration, so much so that the method stands or falls by the validity of this assumption. Thirdly, the regression of estimated area on true area should be as nearly as possible $y=x$ so that no correction is needed in using the estimate for the actual value.

An analysis of variance of the results of the laboratory trial showed that there were no differences between the observers nor between the sides of the leaf, nor did either of these factors interact with each other or with type of plant. The variation of the difference between the mean of the eight determinations and the true area was negligible in relation to the variation in true area, the standard errors being respectively 2 and 11 sq. cm. Further statistical analysis showed that the regression of estimate on true area did not differ with type of plant and that the only difference from the line $y=x$ was a slight over-estimate of 0·35 sq. cm., which could be ignored, since the mean leaf area was 24 sq. cm. Hence, the three points discussed in the last paragraph are satisfied, the first two completely, and the third so nearly that it can be covered by the recommendations given in the next section.

The main comparison in the field trial was of the method described here with that of cross-products, and so the results were analysed with this in view. In both methods the variation between estimated area and true area was negligible in comparison with the variation in true area, thus satisfying the main requirements for validity. In using the grid there were slight differences between observers and a small deviation from the line $y=x$, both well within the bounds that could be covered by the recommendations.

The field observations involved in the cross-product and grid methods took effectively the same time, but the former was felt by the observers to give rise to more strain. From the grid the area is read directly, but from lengths and breadths multiplication is necessary to obtain cross-products, and, moreover, a further sample of leaves has to be taken for the determination of regression of area on cross-product. It has been found that these regression lines differ with type of plant, mainly due to differences in length of leaf tip, so that each type of plant requires its own regression sample.

Recommendations

Experience suggests the following recommendations for use in practice. The grid should be made of some transparent material and a card should be placed under the leaf while the grid is placed on top of it. Since leaves tend to hang down from the petiole the numbering on the grid should be as in Fig. 2, i.e. so that the base of the leaf runs along either the top right or the top left side of the grid. Some leaves may be easier to measure from the right and some from the left, and the grid is made symmetrical to allow for either possibility.

Irregularities in leaf shape were found to lead to slightly inaccurate estimates of area. In practice it would be wise to tend to under-estimate leaves which bulged or were pointed and to over-estimate the flatter leaves ; these occurrences would, however, be rare. Asymmetry appeared to be relatively unimportant except where the widest parts of the two sides of the leaf were not the same distance from the base. In that case the measurement should be made of that nearer to the base with the other side along the axis.

It appears that the variation in the method can be neglected as compared with that between leaves. Hence, for determining the total leaf area of plants this method can be recommended as being as accurate as, and more rapid than, that of cross-products which has been widely used.

Summary

A method for the rapid estimation of leaf areas in the field is described. This method is applicable to all leaves which are approximately elliptical in shape. Sources of error have been examined, both in the laboratory and in a preliminary field test.

It is suggested that the new method has certain advantages over techniques previously used for the estimation of leaf areas in cases involving large numbers of determinations.

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EFFECT OF NUTRITIONAL CONDITIONS ON THE GROWTH AND CHEMICAL COMPOSITION OF 'SOURCE' PLANTS AND ON THE ROOTING OF STEM CUTTINGS DERIVED THEREFROM

I. EFFECT ON THE GROWTH OF THE 'SOURCE' PLANTS

By AMBIKA PRASAD

Stem cuttings might become a valuable method of propagation in varieties where it now only occasionally succeeds, if more were known about non-varietal factors that control rooting. Important amongst these factors are the conditions affecting the ' source ' plants before the cuttings are taken (Garner, 1944), and various nutritional treatments (Pearse, 1943, 1946).

' Source ' plants were therefore grown in 1947 for two seasons under different nutritional treatments and their growth and the chemical composition of their leaves were examined in relation to the rooting performance of softwood and hardwood cuttings taken from them.

This paper describes the growth of the ' source ' plants : their chemical composition and the performance of the cuttings will be dealt with in a later communication.

Material

Three varieties were used : (1) *Myrobalan B,* a widely-used plum rootstock whose hardwood cuttings root moderately well and respond markedly to the cultural treatment of the ' source ' plant (Sinha and Vyvyan, 1943), (2) *Golden willow,* which roots very readily, and (3) *Crab C,* a valuable but shy-rooting apple rootstock. The plum and the apple plants were 1-year-old (1947) rooted shoots from stool or layer beds, while the willow had been planted as 1-year-old, 1 ft. cuttings in the previous autumn (1946).

The roots were washed and trimmed to 4 in., and those more than 6 in. from the base of the stem were removed. The stem treatment was designed to stimulate the growth of laterals suitable for cuttings and was therefore varied with the variety. The strong-growing plum was cut back uniformly to 45 cm., the apical 2 cm. alone was removed from the weaker-growing apple. All but one of the 1947 branches were removed from the very vigorous willow, and this branch was cut to 18 cm.

Each plant was then weighed and the diameter of its 1947 piece of stem was determined at its mid-point in the plum and the apple, and 2 in. from its base in the willow.

Methods

Two series of plants, each sown in fine Bedfordshire river sand, were set up.

Series A consisted of Myrobalan B plants grown in pots, at three levels of N and K, viz., high (HH), medium (MM) and low (LL). Twenty-six large and 17 medium-sized, glazed, tubular pots, together with 59 smaller pots, were used. Drainage tubes, which could be opened or closed were fitted, and protected from the sand by sleeves of fine wire gauze. The tops of the pots were fitted with lids of roofing felt as a protection against light and rain.

The capacities of the pots were 50, 35 and 20 lb. of sand respectively.

Series B.—All three varieties were grown in eight concrete beds under four nutritional treatments, viz., HH and LL as in Series A, and HL (high N, low K), and LH (low N, high K). Each bed was 12 ft. long, 4 ft. wide and 1 ft. deep, and was divided by fine wire-gauze partitions into three sections, one for each variety. Two of the beds were chosen at random for each treatment. The floor of each bed sloped towards the centre where there was a 1 in. drainage pipe, closed on the outside by a tap, and protected within from the sand by a fine wire-gauze chamber, which acted also as a well for reading the water table. Each section contained 16 plants, and the beds were protected from rain by garden lights, carried on a 6 ft. high framework. Each bed held $1\frac{3}{4}$ tons of sand, equivalent to 83 lb. per plant. A further two sets of 16 plants were grown as a control in soil (S) nearby.

Nutrient solutions

Batjer and Degman (1940) found that 60 p.p.m. was the optimum concentration for both N and K for 1-year-old apple trees and that variations in the concentration of P had little effect, provided this was not less than 4 p.p.m. Pearse (1946) found that the growth of vine and plum ' source '

plants varied directly, and the rooting capacity of their stem cuttings varied inversely, with the concentration of N. He found that P also had some effect, although the lower of his two concentrations seems to have been less than 4 p.p.m.

In the present experiments, three concentrations of N (200, 67 and 22 p.p.m.) and three of K (225, 75, and 25 p.p.m.) were used. At first there were also three concentrations of P (12, 4 and 1·3 p.p.m.) and these were varied with those of K, but after 5th August, 1948, 12 p.p.m. was used throughout, as low P resulted in acidity which seemed to reduce growth. The concentrations of Mg and Fe were 36 and 10 p.p.m. respectively in all solutions, that of Ca was 200 before, and 120 after, August: the usual minor elements were added. The N was supplied as KNO_3, $Ca(NO_3)_2$ and $NaNO_3$, the P as $NaH_2(PO_4)$, and the Fe as ferric citrate. The solutions were made up with distilled water and were at first diluted with rain water, but later tap water was used. They were supplied to the plants every week, each plant receiving the same quantity of nutrient salts regardless of pot size. Water was also given as required, and the sand was thoroughly leached once a fortnight to prevent accumulation of salts.

Statistical analyses

All analyses of variance, except those for leaf size, were done on the logarithms of the measurements, as recommended by Pearce (1943). In Series A, Yates' (1935) method was used as there were unequal numbers of pots of each size. The complexity of the analysis was further reduced by using the data from only 32 of the 34 pots per treatment, viz., 8 large, 5 medium and 19 small. In series B the values for the diameters were adjusted by co-variance for those in April 1948.

Growth of the source plants in 1948

Only seven branches per plant were allowed to develop, and the length of each, and the number of leaves it had produced, were determined on several occasions during the season. At the end of the season, each stem was cut off 5 cm. from its base, the basal stub being left to provide a framework for new branches in 1949.

The diameter of the 1947 stem was measured at midsummer in Series A and in autumn in both series.

Series A. Effect of level of nutrition and of pot size on Myrobalan B

Shoot lengths and leaf numbers were determined on six occasions from 14th May to 4th October (Fig. 1). The effects of both nutrition and pot size are significant from July onwards, but their interactions are not.

The geometric means of total numbers of leaves per plant, final summed lengths and weights of stems, and the diameters of the 1947 stem at midsummer and autumn are given in Table I. All differences, except those in the initial diameters before the treatments were applied, are very significant.

TABLE I

GROWTH OF MYROBALAN B UNDER HIGH (HH), MEDIUM (MM) AND LOW (LL) LEVELS OF N AND K NUTRITION IN LARGE (L), MEDIUM (M) AND SMALL (S) POTS, ARRANGED ACCORDING TO NUTRITIONAL LEVEL, AND ACCORDING TO POT SIZE. ALL VALUES ARE GEOMETRIC MEANS, DERIVED BY BACK-TRANSFORMATION FROM MEAN LOGARITHMS

	Total number of leaves	Total length 1948 stems cm.	Final weight 1948 stems gm.	Diameter of old (1947) stem			
				2nd January 1948 cm.	9th August 1948 cm.	4th October 1948 cm.	25th August 1949 cm.
Nutritional level :							
HH	364	348	35·1	0·47	0·85	1·10	1·43
MM	266	181	9·1	0·45	0·66	0·80	1·21
LL	189	89	3·2	0·47	0·61	0·68	0·97
P<	*0·001*	*0·001*	*0·001*	n.s.	*0·001*	*0·001*	*0·001*
Pot size							
L	347	266	19·7	0·49	0·81	0·95	1·24
M	251	177	11·0	0·45	0·68	0·80	1·19
S	210	119	4·7	0·45	0·63	0·78	1·14
P<	*0·001*	*0·001*	*0·001*	n.s.	*0·001*	*0·001*	n.s.

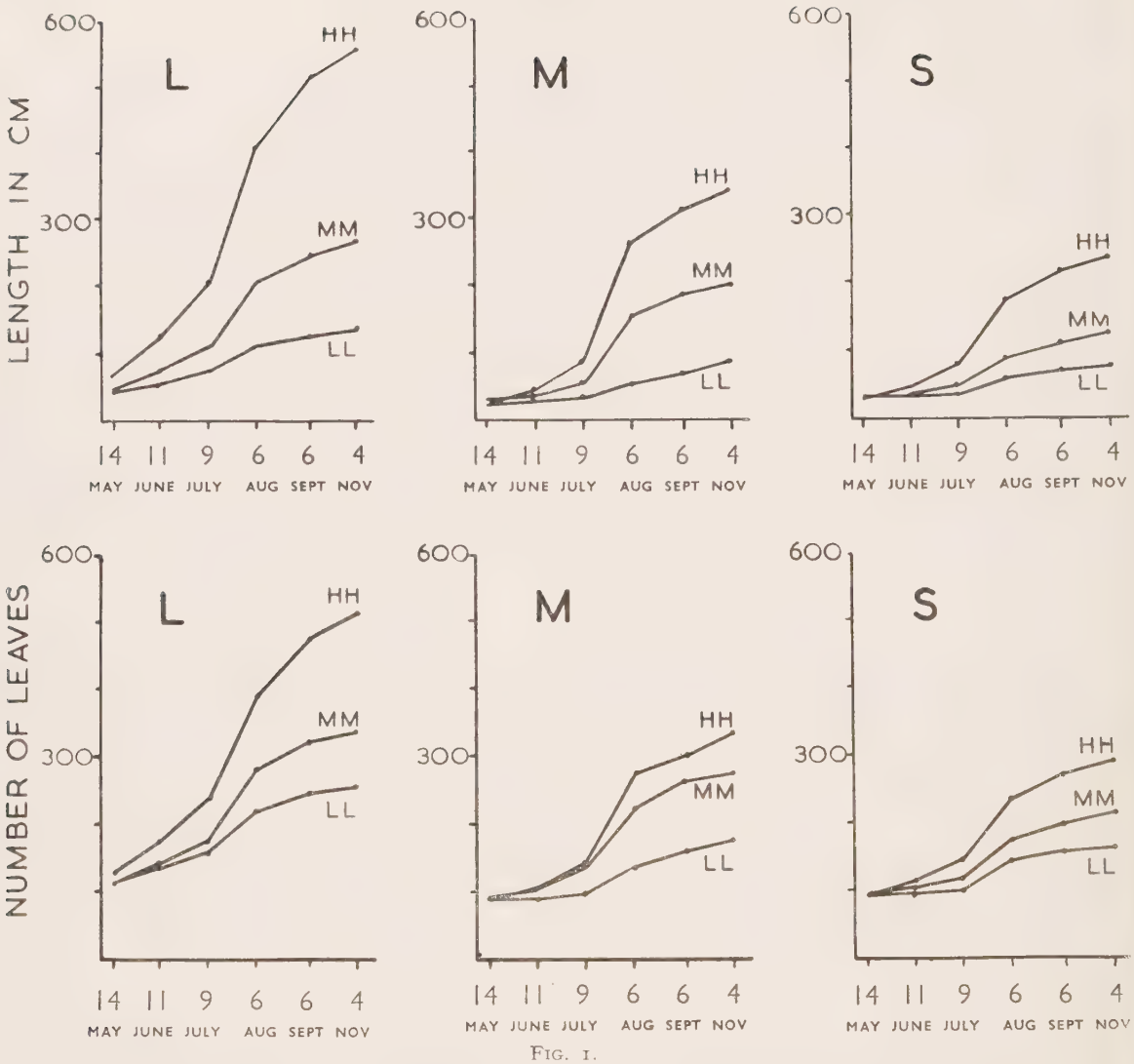

Fig. 1.

Summed length of new shoots and total number of leaves produced per plant in Myrobalan B plants grown under high (HH), medium (MM), and low (LL) levels of N and K nutrition in large (L), medium (M) and small (S) pots.

Series B. Effect of total and relative levels of N and K nutrition

The results, given in Fig. 2 and Table II, show that the plum and willow behaved much alike and differently from the apple. Shoot growth under treatment HH continued in the plum with undiminished vigour until the end of the season, but in the willow it slowed down. Under treatment S, however, shoot growth in the plum was at first more rapid than under treatment HH, but it slowed down in August and almost ceased in September. In the apple, growth was much greater in soil (S) than under any nutritional treatment in sand ; it was very rapid in August and then slowed down, while under the other treatments it was slow until August and then usually became more rapid. The poor growth under treatment HL was probably due to the high pH values found in the early part of 1948.

Effect on leaf size and shape in the willow

Random samples of leaves from leading shoots were measured (Table III). The values for length, width and L×W in August are in the same order as those in Table II, indicating that they are reliable measurements of plant size. In October, the values for HL became relatively higher and no longer significantly lower than those for S, probably because acidity was reduced after the concentration of P was raised. The significant differences in the values for L/W in October indicate differences in leaf shape ; these values tended to vary inversely with those of L×W or relative area.

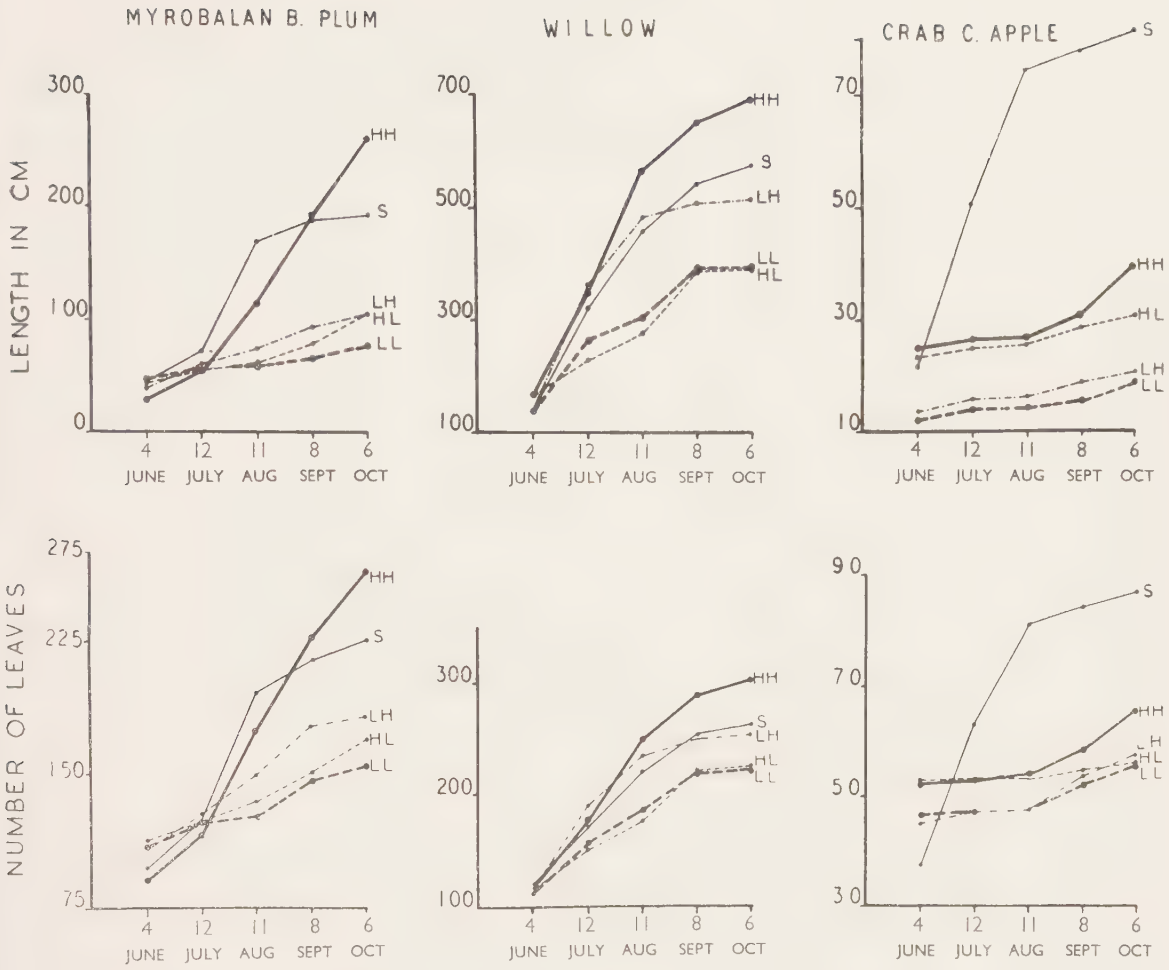

Fig. 2.

Summed length of new shoots and total number of leaves produced per plant in Myrobalan B, Willow and Crab C plants grown under conditions of high N high K (HH), high N low K (HL), low N high K (LH), low N low K (LL) and in soil (S).

Growth of source plants in 1949

Relative stage in development of buds in the spring of 1949

Five buds, representing progressive stages from bud swell onwards were selected from the plum plants, arranged in order, photographed, and given serial category numbers (Fig. 3). Each swollen or open bud on every plum plant was compared with the photograph and allotted to its respective category. In the willow, four buds were selected and photographed instead of five (Fig. 3), and these thus became the dividing points between the five categories, instead of their mid-points as in the plum.

The number of buds to break dormancy will depend, in part, on tree size ; the mean category number should indicate their mean stage in development (Table IV).

Series A.—Mean number of burst buds varies directly, and mean stage in development indirectly, with level of nutrition ; pot size had no consistent effect.

Series B.—The number of burst buds was greatest under HH, but this was significant only in the willow. The stage in bud development in the plum tended to vary inversely with tree size.

Series A. Effect of level of nutrition and pot size

On three occasions two of the longer shoots per plant were removed as cuttings (Fig. 4). The summed lengths of the residual shoots in autumn were 393, 272 and 135 respectively in treatments HH, MM, and LL. The differences between the diameters under the three treatments are in the same order and very significant (Table II) ; pot size here had little effect.

TABLE II

GROWTH OF MYROBALAN B, GOLDEN WILLOW, AND CRAB C IN 1948 AND 1949 UNDER HIGH N AND K (HH), LOW N AND K (LL), HIGH N LOW K (HL), LOW N HIGH K (LH), AND IN SOIL (S).
ALL VALUES ARE GEOMETRIC MEANS.

Variety and Treatment	Growth in 1948				Growth in 1949		
	Total number of leaves	Total length 1948 stems cm.	Final weight 1948 stems gm.	Diameter 1947 stem* cm.	Treatment	Residual length 1949 stems cm.	Diameter 1947 stem cm.
Myrobalan B	*6th October*	*6th October*	*6th October*	*4th October*		*28th August*	*4th September*
HH ..	275	272	21·6	0·87	HH	562	1·47
S ..	202	180	12·7	0·81	HL	237	1·00
LH ..	170	111	5·6	0·70	S	254	0·98
LL ..	160	90	3·9	0·63	LL	95	0·87
HL ..	151	88	3·9	0·59	LH	54	0·85
P< ..	*0·05*	*0·01*	*0·01*	*0·05*		*0·05*	*0·01*
Willow	*6th October*	*6th October*	*6th October*	*4th October*		*1st September*	*14th August*
HH ..	300	684	123·0	1·33	HH	1,023	2·04
S ..	247	550	81·3	1·29	HL	813	1·81
LH ..	236	465	47·9	1·09	S	403	1·66
HL ..	228	395	43·2	1·02	LH	292	1·40
LL ..	219	389	35·5	0·98	LL	232	1·24
P< ..	*0·01*	*0·01*	*0·01*	*0·01*		*0·05*	*0·01*
Crab C	*6th October*	*6th October*	*6th October*	*4th October*		*6th October*	*13th August*
S ..	87	86	9·5	0·85	S	95	1·06
HH ..	56	26	1·8	0·78	HH	38	0·88
LH ..	54	23	1·1	0·75	HL	19	0·88
LL ..	53	22	1·1	0·74	LH	7	0·83
HL ..	48	22	1·1	0·74	LL	3	0·79
P< ..	*0·01*	*0·001*	*0·01*	*0·01*		*0·001*	*0·001*

Ratios between bracketed values not significantly different from 1·0 ($P=0·05$).
* Adjusted by covariance for initial diameters (2nd April, 1948). Mean initial diameters were 0·51, 0 74 and 0·72 in the plum, willow and apple respectively.

TABLE III

EFFECT OF NUTRITIONAL TREATMENT ON LEAF SIZE AND SHAPE IN THE WILLOW
MEAN VALUES BASED ON FOUR PLANTS PER TREATMENT

	Length cms.		Width cms.		Length × Width		Length/Width	
4th September, 1948	HH	11·2	HH	1·9	HH	22·2	LH	6·8
	S	9·9	S	1·6	S	17·0	HL	6·6
	LH	9·8	LH	1·5	LH	14·5	LL	6·4
	HL	8·0	HL	1·3	HL	10·3	S	6·3
	LL	7·7	LL	1·2	LL	9·7	HH	6·1
P<		*0·01*		*0·01*		*0·001*		n.s.
7th October, 1948	HH	12·2	HH	2·4	HH	30·2	LH	7·6
	LH	11·0	S	1·9	S	19·5	LL	6·7
	S	10·0	HL	1·7	HL	18·2	HL	6·0
	HL	9·9	LH	1·5	LH	17·1	S	5·3
	LL	8·3	LL	1·3	LL	11·1	HH	5·1
P<		*0·05*		*0·001*		*0·001*		*0·01*

Series B. Effect of total and relative levels of N and K nutrition

The mean length of the two shoots removed as cuttings from the plum and the willow on various dates are shown in Fig. 4. The summed lengths of the residual shoots on all three kinds of plant, and the diameters of their 1947 stems in the autumn, are given in Table II. In both the plum and the willow the treatment HL was now nearly as successful as HH.

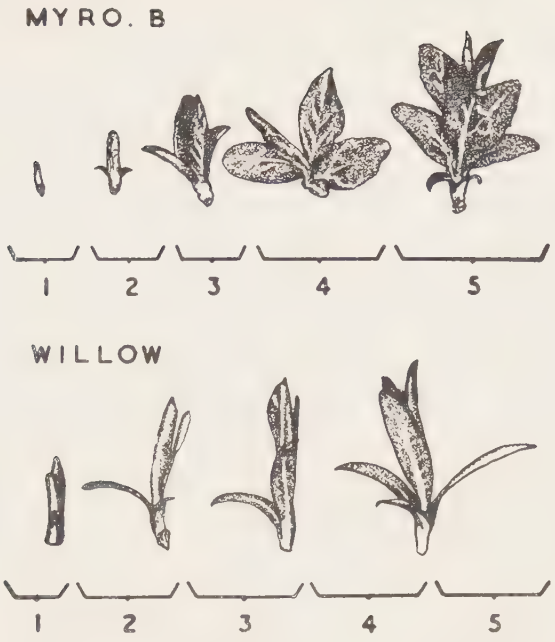

FIG. 3.

Line drawings from the photographs of buds of Myrobalan B and Willow in different stages of development in the spring of 1949, and the five categories, 1–5, based thereon.

TABLE IV

EFFECT OF TREATMENT ON NUMBER OF BUDS THAT BROKE DORMANCY IN THE FIRST WEEK OF APRIL, 1949 AND ON THEIR MEAN STAGE IN DEVELOPMENT

	Series A			Series B					
	Myrobalan B			Myrobalan B			Willow		
	Treatment	Mean Number	*Mean Stage	Treatment	Mean Number	*Mean Stage	Treatment	Mean Number	*Mean Stage
Nutritional Level	HH	35·9	1·86	HH	33·8	2·46	HH	26·3	1·79
	MM	32·6	2·05						
	LL	28·4	2·51	S	28·5	2·63	S	20·2	1·65
	P<	*0·01*	*0·001*	LH	28·5	2·80	HL	18·9	1·81
Pot Size	L	35·8	2·09	LL	29·8	3·25	LH	18·8	1·70
	M	29·9	2·02						
	S	31·2	2·30	HL	28·5	3·55	LL	18·6	1·54
	P<	*0·05*	*0·05*	*P*<	n.s.	*0·001*	*P*<	*0·001*	n.s.

*=S xy/100, where x is category (Fig. 3) and y is per cent in category.

Discussion

Plum plants were grown in three sizes of pot under high, medium and low levels of nutrition. The marked effect of pot size on growth showed that factors other than nutritional concentration were important; one of these may have been root run, which will have been restricted in small pots.

Plum and willow grew best under high N and K nutrition in sand; next best in soil. Growth under high N low K treatment was poor in 1948, probably because P was kept low until August and acidity became high: in 1949, however, it was nearly as good as under high N high K, suggesting that N rather than K was the controlling factor. The apple grew poorly under all nutritional treatments in sand but comparatively well in soil. Though the spacing within and between the varieties was the same in sand as in soil, the competition may have been greater in the sand where root run was restricted by the walls and floor than in soil where there were no restrictions.

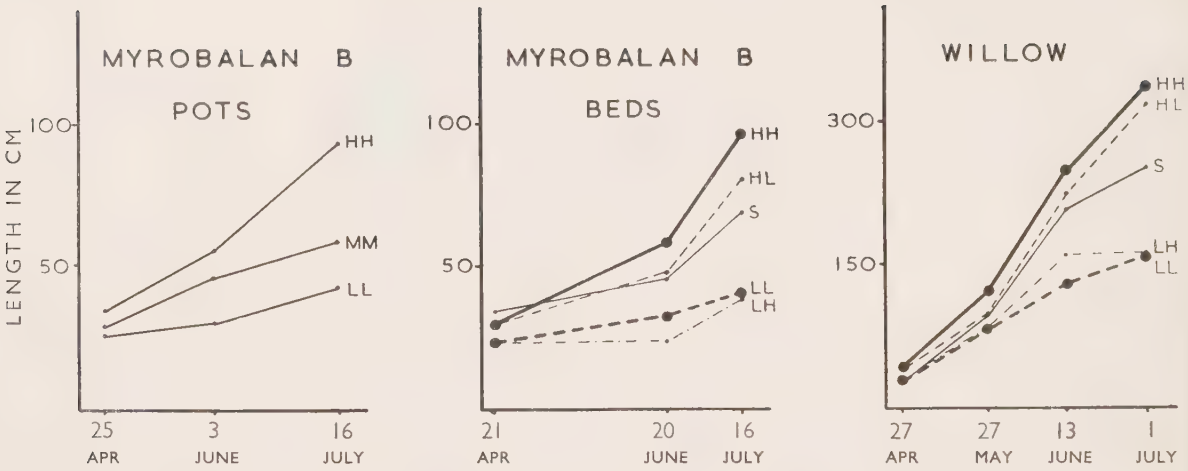

FIG. 4.

Length of two of the longest shoots per plant, when removed for use as softwood cuttings.

The apparent effects of the various treatments were much the same whether they were measured by counting the leaves, or determining the lengths or weights of the stems, but the relative values were different. Thus, as shown in Table I under HH the stems of the plum were more than five times as heavy and about three times as long as those under LL, but bore only 70 per cent more leaves, indicating that internode length was less under treatment LL ; this factor might affect rooting capacity.

Summary

A plum rootstock (Myrobalan B), apple rootstock (Crab C) and the golden willow were grown under a series of nutritional conditions for two seasons and used as sources for softwood and hardwood stem cuttings. The effect of these conditions on the growth and chemical composition of the source plants and on the rooting of the cuttings was examined, but only the growth is reported here. The growth of the three varieties varied directly with the level of N and K, and with pot size ; there was no interaction.

When the three varieties were grown side by side under high (HH) low (LL), high N low K (HL), low N high K (LH), and in soil (S), the plum and the willow grew best under HH with soil (S) as next best. The apple grew best under S and very poorly under all other treatments.

Increase in stem growth involved longer internodes as well as more leaves, which in the case of the willow were broader and larger. There was some indication that buds in 1949 burst earlier in trees under treatments that produced poor growth in 1948.

Acknowledgments

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PLANT PATHOLOGY

THE PRODUCTION AND DISTRIBUTION OF VIRUS-FREE FRUIT TREES AT EAST MALLING*

By R. V. HARRIS and A. F. POSNETTE

At the 13th Horticultural Congress (1952), one of us outlined a scheme for producing fruit clones with minimal virus infection and maintaining them in commercial cultivation (Harris, 1953). These proposals were based on the current information from research in Great Britain on the etiology and control of soft-fruit virus diseases, particularly those of raspberry and strawberry, and only passing reference was made to the analogous problem raised by the corresponding tree-fruit diseases. Since 1952, substantial advances have been made at East Malling, both in the identification of these diseases and their pathogens and in the selection, propagation, and maintenance of virus-free rootstock and scion sources. The present communication is concerned with these results and their application to modern horticultural nursery practice.

A basic system

The proposed scheme consisted of the following three stages :

(1) The selection of virus-free clones by indexing ; their maintenance and the propagation of *Nuclear Stock* from them.

(2) The propagation of these nuclear stocks, under conditions assuring the maintenance of their health, to the quantity required for the distribution of *Elite Stock* to the commercial propagator of certified stock.

(3) The commercial propagation of Elite Stock under appropriate health-certification schemes for supplying the fruit growers with *Special Stock*.

The scheme is based on the principle of periodic re-issues of tested stock from source, but the frequency of such re-issues would clearly depend on the relative susceptibility of the particular crop to re-infection under plantation conditions. The scheme is applicable to crops affected by viruses with a limited range of hosts and of natural vectors, and therefore susceptible to control by reasonable isolation and vector control.

Stage 1 is clearly integral with general research on the relevant diseases and can therefore be operated most effectively by the pathology and pomology staffs of the appropriate research institutions.

Stage 2 requires isolation (or equivalent protection) and special procedures to minimize the risks of re-infection in the earliest stages of field multiplication, so that the commercial propagators receive elite stock in a state of health equivalent to that of the tested nuclear stock. The relatively rapid spread of the constituent viruses of the decline complexes of strawberries and raspberries has necessitated periodic replacements with nuclear stock of each variety from source. With strawberries, for example, this must be multiplied by propagation in two successive years to a gross output of about 600,000 elite plants per annum to meet the present demand by the commercial propagators.

This intermediate stage of strawberry propagation for England and Wales is now operated by a non-profit-making co-operative association set up by the industry, under the sponsorship of the National Farmers' Union, and known as the Nuclear Stocks Association Ltd., The Ministry of Agriculture and Fisheries has vested its entire Special Stock certificate scheme for strawberries in the products of this Association, and so defines the technical requirements covering the two-year process of multiplication to the elite stage, and also inspects and certifies the products of each year's propagation ; this is followed by inspection during the final year of commercial propagation for the S.S. certificate. The Ministry and the Association are advised on varieties to be included in this scheme by a representative sub-committee of the National Fruit Trials Committee of the National Agricultural Advisory Service, and thereby hope to ensure the introduction of promising new varieties to the industry as virus-free stock. The Association collaborates with the appropriate Research Institutes, and East Malling has accepted responsibility for issuing every year, as far as it is available, nuclear stock of those strawberry varieties chosen by the Association for the production of elite stock.

This system, now operating in England and Wales with strawberries, can be used as a model for a

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fruit tree scheme. Let us consider what modifications are required to allow for the differences between soft fruits and tree fruits and their respective diseases.

Application to fruit trees

Firstly, the longer commercial life of the tree compared with that of the strawberry plant, and the fewer trees required per acre, mean that the annual propagation of fruit trees is on a numerically smaller scale than that of soft-fruit plants. Also, the composite nature of the tree (rootstock and scion) involves procedures more complex than those for strawberry propagation.

Secondly, the spread of viruses by vectors among fruit trees is probably much less rapid than among soft fruit plants ; indeed there is evidence that many of the prevalent viruses usually spread by being propagated with their host plants, and rarely, if at all, by insects. The dual source of infection, rootstock and scion, provides ample opportunity for the synthesis of complexes.

Both these differences suggest that frequent re-issues of nuclear stock of fruit-tree clones will be unnecessary, and that reformed nursery practice, referred to later, may be sufficient to ensure that an issue of tested material of each scion and rootstock variety will remain healthy for many years.

We have not yet had sufficient experience of the virus-tested clones of fruit trees to be able to predict with any certainty how long they will remain healthy. Our investigations up to now have been concerned mainly with stage 1 of the scheme, i.e., the testing, selection, and propagation of a virus-free nucleus of rootstocks and scion varieties of apple, pear, and *Prunus* spp. Because propagation has presented few difficulties so far, and there seems no reason at present to anticipate any with the maintenance of the health of these selections, the remainder of this paper is devoted chiefly to the methods used in the selection of virus-free clones.

Selection of virus-free material

Four procedures are open to us when a virus-free clone of a particular variety is required. The simplest is, of course, to obtain one ready-made from another worker who has satisfied himself that the clone is virus-free. Material introduced from another country should be re-indexed, however, because it is possible, although we know of no instances, that a latent virus may become manifest in a different environment, and different varieties of indicator plants may be available. Such exchanges of indexed material seem to us most desirable, not only for the obvious reason of avoiding unnecessary duplication of effort, but because the subjection of the selected clone to tests by different workers provides the best insurance that it is in fact virus-free.

When no tested material of a variety can be introduced, the usual procedure is to select a number of plants that appear to be healthy and to subject them to a series of tests for virus infection. This presupposes that the basic research on methods of testing for infection in the particular host has been completed (Cropley, 1954). Speaking of plant virus diseases in general, there are chemical tests for infection, like the methyl alcohol test for phony peach (Hutchins, 1933) and Lindner's staining test (Lindner, *et al.*, 1951) ; histological tests like that for rubbery wood of apple (Beakbane and Thompson, 1945 ; Prentice, 1950) and serological tests for many viruses, as for example, in potato. With fruit trees, however, indexing—the inoculation of indicator plants—remains the standard test, and scope for ingenuity is confined to the choice of indicator varieties, and the manipulation of test plants to obtain simplified techniques and rapid production of symptoms.

Before discussing such indexing, we must mention the two other procedures for obtaining virus-free clones. When the results of indexing many apparently healthy plants suggest that all of a particular variety are infected, virus-free material may be obtained by prolonged heat treatment similar to that successfully applied to the soft fruits (Posnette *et al.*, 1953 ; Chambers, 1954). Few of our fruit-tree varieties have yet been subjected to this type of heat treatment, but experiments with apple mosaic have shown the potentialities of the method. Several investigators have tried and failed to inactivate apple mosaic virus by warm water treatment as used successfully for peach viruses of the yellows group. We found, however, that apple mosaic is inactivated by maintaining young apple plants at air-temperatures of 37° C. for 4 weeks.

The fourth method of obtaining virus-free material from an infected clone is by propagating from young, actively growing shoots. This procedure may either be combined with heat treatment to obtain virus-free budwood from treated plants which are not permanently cured, or used without heat treatment for hosts within which certain viruses do not become fully systemic, e.g., apple mosaic.

All these four methods of obtaining virus-free clones depend finally on the efficiency of the indexing method. Indicator tests become increasingly stringent as new hosts are discovered—witness the effect of the *Prunus serrulata* test on stone fruit selection : some clones which seemed virus-free when indexed on peach and Montmorency proved to be infected when indexed on Shirofugen and Kanzan (Milbrath and Zeller, 1945).

Stone fruits

Indicators for stone fruit viruses have been investigated for so long and by so many workers that it seems unlikely that new ones of value will be found. We claim, however, that the mazzard clone F12/1 is a useful indicator for most cherry viruses, including some that do not cause symptoms on peach and Shirofugen ; and being readily propagated by layering, F12/1 is a convenient first " screen " in testing for virus freedom (Posnette, 1954a). In virus tests with cherries, we have used the varieties Shirofugen, Montmorency, Bing, Napoleon, Hedelfingen and Early Rivers, and seedlings of apricot, peach, mahaleb, mazzard, sour cherry, *Prunus tomentosa*, and myrobalan. We now consider that indexing on F12/1, peach, and Shirofugen will indicate all the viruses which we have encountered, with the reservation that we have not yet used Kanzan, which was reported by Milbrath and Zeller (1945) to react to strains of ring spot virus which caused no symptoms on Shirofugen and peach.

In testing clones of plum varieties we have relied mainly on the established indicators, Italian Prune (for prune dwarf virus), Shiro plum (for line pattern virus), Shirofugen and peach seedlings (for ring spot virus). We have been disappointed with the sensitivity of Shiro plum to our strains of line pattern and have found myrobalan seedlings and Early Laxton plum more sensitive. We have had also to introduce a new indicator, Cambridge Gage, into our range to test for the recently described bark split virus (Posnette, 1953b).

Few tests have been attempted on peach and apricot varieties because they are not grown extensively in Britain. However, the attention of other workers on these crops should perhaps be drawn to the prevalence in them (and also in plum and cherry) of a latent virus that induces an inconspicuous dark green mottle on the leaves of inoculated peach seedlings (Posnette, 1954a).

Pome fruits

Until recent years, virus diseases of apples and pears had received little attention and the production of virus-tested clones had not been attempted. The prevalence of the rubbery wood virus in apples revealed by extensive testing of rootstock clones and scion varieties (Luckwill, 1954 ; Posnette and Cropley, 1954), and the discovery that varieties other than Lord Lambourne are sensitive, has forced us to devote considerable time to the selection of virus-free material. So far, the variety Lord Lambourne, which is sensitive to the rubbery wood, mosaic and chat fruit viruses, is the only indicator extensively used for apples ; the reliability of the peach-seedling test for rubbery wood virus is now being investigated (Posnette, 1953c).

Pears have posed unexpected problems. When we started indexing pears, the only virus diseases previously reported were stony pit and mosaic. We have found two others widely distributed in pear trees without fruit symptoms of stony pit, one of these viruses being present also in the Malling rootstock clone, Quince C. The other clonal quince rootstocks in commercial use, A and B, have proved useless as indicators, and quince seedlings are the best we have used for this purpose. A genetical abnormality, similar to " white crinkle " in cherries, is common in quince seedlings, and affected plants are poor virus indicators. We have found that most open-pollinated seedlings of Quince E are normal and at least two-thirds of them are good indicators. New clones are being propagated from sensitive seedlings.

Quince seedlings have not developed symptoms until the year following inoculation, even if infected as young seedlings in May and kept in the glasshouse. In the search for a more sensitive indicator, we have inoculated young seedlings of hawthorn (*Crataegus oxyacantha*), mountain ash (*Sorbus aucuparia*), and apple, but these have proved less sensitive than quince. *Amelanchier* seedlings are now being tried (*A. canadensis, cretica, florida, glandulifolia, indemedia,* and *spicata*).

Propagation of selected clones

After the selection and testing procedures have been completed, the propagation of virus-free material of scion varieties depends on a supply of virus-free rootstocks. As the ring spot virus is seed-transmitted in *Prunus*, and the seed transmission of apple and pear viruses has not been fully investigated, seedlings can safely be used as rootstocks only if they have been raised from virus-free mother trees. Clonal (vegetatively propagated) rootstocks are generally preferred in Europe and established stoolbeds are already in production in most countries. These stoolbeds can be tested either by indexing a sample of stools on the standard range of indicators, or by harvesting the stocks separately from individual stools and using them as rootstocks for indicator varieties. If some, but not all, of the stools are found to be infected, fresh stoolbeds can be laid down with material from the virus-free stools. While the new beds are coming into production, rootstocks from the old tested stools can be harvested for immediate use. If a scatter of infection is suspected in an established stoolbed which is too extensive for all the stools to be tested, it would be preferable to index every stool in a short length, rather than a random sample. When infected stools have been removed, a section of the bed is then available from which healthy rootstocks can be harvested without danger of " contamination ".

Fortunately, at the outset of these investigations one clonal rootstock from each of the original apple, quince and cherry series proved to be apparently free from virus infection ; only for plums we have no rootstock clone entirely virus-free. We are now propagating our rootstock clones from virus-tested plants, five sub-clones of each type, while tests for viruses that produce symptoms only on the fruit are in progress.

Maintenance of virus-free clones

Once virus-free selections of scion varieties and rootstocks have been propagated, we have to consider procedures for maintaining them in a healthy condition during the period of their distribution to fruit growers.

Such evidence as there is on the spread of virus diseases of fruit trees suggests that most of the viruses prevalent in England are mainly spread in the process of propagation by the use of infected scions or rootstocks. This statement is based on the virus distribution in long-established stoolbeds and in orchards (as disclosed by indexing) of the following diseases : Rusty Mottle and Ring Mottle of sweet cherry, Bark Split in plums, Mosaic and Rubbery Wood of apple, and the Quince C virus in pears and quinces.

There is evidence, on the other hand, of orchard spread of Tatter Leaf, Leaf Roll (Posnette and Cropley, 1955) and Necrotic Line pattern of sweet cherry, so that we must consider means of preventing the infection of the virus-free clones by insect vectors. The degree of isolation necessary to exclude the causal viruses cannot be assessed however, until their vectors are known, or until we have gained more experience of their spread in practice. At East Malling we are concentrating on the elimination of those diseases that are spread during propagation. We are trying to impress the grower with the necessity of using virus-free material, and of avoiding such malpractices as re-budding or grafting rootstocks on which buds or grafts have failed ; or alternatively, of returning such " failed " trees to the stoolbed for rootstock propagation (Posnette, 1954b ; Harris, 1955).

Virus-tested rootstocks are the first necessity for the nurseryman ; if these are not available, it is useless to distribute virus-free scion material. A set of virus-free apple rootstocks (the MM series) has already been issued, and we are preparing to re-issue the old M series, and Brompton and Myrobalan B plum stocks, as virus-tested clones. The F12/1 mazzard cherry stock and Quince A are also being re-cloned from virus-tested plants, although we have not found any infection of these last two types in our own stoolbeds.

With scion varieties we are following the principle of distributing " mother trees " as sources of scion wood for grafting on to virus-free stocks. As a virus-free stock for cherries, F12/1, is already extensively used, we were able to start distributing mother-trees of cherry varieties in 1953 ; eleven commercial varieties are now available as virus-free mother trees, and more will be added each year as they are tested and propagated.

A plot for virus-free trees of commercial varieties of all the tree fruits has been established at East Malling and is being extended as new material comes to light in the virus tests. This " Stock Tree plot " will provide a nucleus from which mother trees can be propagated to meet the demand from commerce, and also to supply the experimental trees required by the Research Station. How long these " stock trees " and the " mother trees " used by nurserymen will remain healthy we have, at the moment, no means of judging. We may find, after periodic re-indexing, that fresh issues are required after every few years, but we anticipate that apple and pear trees will remain uninfected for many years, while stone fruit trees may well require at least relative isolation from sources of such viruses as tatter leaf and leaf roll.

Summary.

The nuclear-stock system at present operating for the production and maintenance of healthy clones of the soft-fruits is in course of application to the tree-fruit crops, with modifications appropriate to differences in their propagation and in their virus diseases. Scion mother trees of some cherry varieties have already been made available to nurserymen and the work is being extended to include plums, apples and pears.

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STRAWBERRY MOSAIC VIRUS DISEASE

By A. F. POSNETTE

In 1952, some Royal Sovereign strawberry plants with an unusual yellow mottle on their leaves were received from Mr. L. Ogilvie (Plant Pathologist, National Agricultural Advisory Service), who had collected them in the Cheddar district of Somerset. In 1953, Miss J. M. Buttfield (N.A.A.S.) collected some similar plants in Kent, but no other outbreaks are known. These two sets of plants have been grown in the glasshouse at East Malling, and it is now certain that the plants from Cheddar are infected with a virus disease not previously reported. While the Kentish plants have shown somewhat different symptoms, the resemblance is sufficiently close to justify including both types under the same disease name—Strawberry Mosaic—on the assumption that different strains of the same virus are concerned.

Symptoms

The following description applies to Royal Sovereign plants, the only variety so far known to be infected. Infected plants are stunted, with small, distorted leaves, the leaflets being constricted at the base and puckered (Fig. 1). Yellow areas of variable size and shape occur irregularly over the leaf, tending to be larger near the midrib and at the base of the leaflets (Fig. 2). Necrotic spots are absent except when the plants are also infected with the crinkle virus. Plants infected with Strawberry Mosaic, particularly its Kentish ' strain ', seem to be more severely damaged by Mildew than are healthy plants.

Transmission

The virus causing Mosaic has been transmitted by grafting stolons of healthy Royal Sovereign plants to petioles of infected plants. Symptoms developed 8 weeks after grafting.

The Strawberry Aphid, *Pentatrichopus fragaefolii* (Cock.), has failed consistently to transmit the mosaic virus when feeding times were adjusted suitably for the transmission of the yellow edge and crinkle viruses. The aphids did, in fact, transmit both Mild Crinkle (virus 1, Prentice and Harris, 1946) and Crinkle (virus 3, Prentice, 1949) from plants having Mosaic.

Summary

A virus disease of strawberry, characterized by large yellow areas on the leaves, is described under the name Strawberry Mosaic.

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Fig. 1
Strawberry Mosaic on Royal Sovereign

Fig. 2
Roval Sovereign leaf showing distortion and the distribution of chlorotic areas typical of Mosaic disease.

AN EPIDEMIC LEAF SPOT AND SPUR WILT OF CHERRY CAUSED BY *PSEUDOMONAS MORS-PRUNORUM*

By J. E. CROSSE

In the Bacterial Canker and Leaf Spot disease of cherry caused by *Pseudomonas mors-prunorum*, a winter canker stage on the phloem and cortical tissues of the stems and branches alternates with a summer stage on the leaves and, in certain years, on the green extension shoots. In May 1953, a completely new form of the summer stage was observed consisting of a wilting of the fruiting spurs. Associated with this was a bacterial leaf spotting of abnormal severity.

The first notification of the outbreak was received from an orchard near Faversham, Kent, on 21st May. Similar reports were subsequently received from all the major cherry districts of Kent and it became clear that the disease had reached epidemic proportions.

Symptoms

Trees of all ages were attacked, but it was on those in full cropping that the disease caused most concern. On some it was estimated that 30 per cent of the fruiting spurs were affected, a figure which represented a substantial loss in the immediate and future cropping potential of the trees. Both Leaf Spot and Spur Wilt were spread more or less uniformly throughout the trees. This was in marked contrast to normal years when leaf infections are comparatively few and sporadically distributed, usually in the form of small ' flushes ' near to the cankers which constitute the over-wintered source of infection. It appeared, therefore, that conditions had occurred in 1953 leading to the widespread distribution of inoculum throughout the affected trees.

Leaf spots were of the normal type, but the rate of infection on individual leaves was very high and often resulted in complete necrosis of the entire margin and apex of the leaf (Fig. 1) ; lesions were also common on the petioles.

Most of the Spur Wilt was due to infection of the axis of the current year's spur growth, either directly or indirectly through the petiole bases. In the early stages there was a diffuse waterlogged necrosis of the cortical tissues and in these bacterial masses were readily located. Later, characteristic black lesions appeared on the surface of the spur axis (Fig. 2). Where these girdled, the spurs had collapsed, usually in full leaf and after the fruit had set. The leaves withered and turned brown and there was considerable defoliation (Fig. 3).

Spur Wilt sometimes occurred in the absence of lesions on the young growth. In such cases an infection was invariably located in the distal parts of the previous years' spur growth in the region where the flower buds were seated. These infections probably originated indirectly from diseased flower peduncles.

Both Leaf Spot and Spur Wilt were outstandingly severe on the variety Early Rivers, but other early flowering varieties, e.g., Knight's Early Black and Bedford Prolific also suffered severely. In some localities the mid-season varieties Roundel, Frogmore, and Napoleon were affected to some degree, but no reports were received of the infection of late flowering varieties such as Florence and Bradbourne Black.

Casual organism

Thirty-five isolations from infected leaf and spur material, collected from seven different and widely separated localities, all yielded *Ps. mors-prunorum*. This organism is distinguished from the related cherry pathogen, *Ps. syringae* Van Hall (syn. *Ps. prunicola* Wormald) by its growth characteristics on nutrient agar plus 5 per cent sucrose, on 2 per cent purple lactose agar, in nutrient broth plus 5 per cent sucrose, and on gelatin and in lactose and maltose broths (Wormald, 1932 ; Crosse, 1953).

Epidemiology

The exceptional nature of the outbreak was attributed to the rare coincidence of two main predisposing factors, namely weather conditions highly conducive to infection, and a maximum state of host infectibility.

Infection conditions

The epidemic was associated with unusual weather conditions at the end of April, approximately three weeks before the receipt of the first diseased material.

Following four consecutive wet days, 1·48 in. of rain fell at East Malling between the morning of 30th April and midnight of 1st May and at one stage was continuous for almost 24 hours. The highest rainfall of the year was recorded in the 24-hour period beginning 09.00 hours on 30th April. The amount of this rainfall can be judged by comparison with the monthly average over the last 35 years for the whole of April of 1·65 in. There was no sunshine on either day and on 1st May relative humidity rose to 95 per cent. The whole period was characterized by strong winds, reaching Force 6 (Beaufort Scale) with gusts of over 35 m.p.h. on 30th April and Force 5 with frequent gusts exceeding 25 m.p.h. on 1st May.

Similar conditions were recorded at the meteorological sub-station at Throwley, approximately 18 miles east of East Malling and very near to the locality from which the outbreak was first reported. In a period of more than 24 hours continuous rain, 1·58 in. were recorded. There was no sunshine on either day and on 1st May relative humidity rose to 100 per cent. Winds reached moderate gale force (Force 7) on 30th April.

The unusual nature of this weather was confirmed by an examination of meteorological records back to 1943. At no time had comparable conditions occurred during the flowering period of cherry except, perhaps, in the wet April of 1946 when there was a total rainfall of 2·14 in. between 27th and 29th April inclusive, with no sunshine at all on the 28th and 29th. On none of these days, however, did winds exceed Force 1.

Rain is known to be an important factor in the Bacteriosis disease of cherry, both Leaf Spot and Canker being usually more severe after a wet spring or autumn respectively. From a comparison of conditions in 1946 and 1953, however, it was concluded that wind-driven rain was the main predisposing factor in the present epidemic. It is clear that such conditions would account for the apparent widespread distribution of inoculum through infected trees, particularly as the winds were southerly on 30th April and northerly on 1st May.

Driving rain has been previously shown to be important in other bacterial diseases. In Bacterial Blight of cotton (*Xanthomonas malvaccarum*), for example, it is the chief vehicle for the dissemination of inoculum within new crops (Faulwetter, 1917 ; Massey, 1929 ; Andrews, 1936) ; it plays a similar role in epidemic Wildfire of tobacco caused by *Pseudomonas tabaci* (Chapman and Anderson, 1921). In both these diseases driving rain also facilitates the entrance of bacteria into the leaves. Thus, in Wildfire it penetrates the stomata causing a temporary water congestion of the intercellular spaces (Clayton, 1936). Bacteria are either carried in during this process or enter in the continuous liquid passage thus provided between the exterior and the interior of the leaf (Diachun *et al.*, 1942). A similar mechanism is apparently involved in Bacterial Blight of cotton (Weindling, 1948).

The unusually high number of lesions per leaf and the unprecedented nature of the Spur Wilt suggested that the latter factor may have been operative in the present epidemic. This possibility was tested experimentally.

Infection experiment.—In February, three-year-old potted cherry trees of the varieties Roundel and Napoleon were brought into the greenhouse to promote early bud break and flowering. At the time of the experiment, on 7th April, petal fall was complete on Roundel and at about the 60 per cent stage on Napoleon. The leaves on both varieties were fully expanded, but were about half the mature size. The trees were infected with strain C1/55 of *Ps. mors-prunorum*, isolated seventeen days previously from a diseased cherry spur. Inoculum was prepared by suspending a two-days bacterial growth on nutrient agar plus 2 per cent glycerine in sterile distilled water.

Driving rain was simulated by spraying water or bacterial suspensions under pressure (15 lb. per sq. in.) from an ' Aerograph ' atomizer gun fitted with a coarse (No. 3) nozzle. Spraying leaves by this means induced water congestion of the intercellular spaces, but only when the spray was directed against the lower surface. Spraying the upper leaf surface caused no congestion. This difference was associated with the distribution of the stomata, which are mainly, if not entirely, confined to the lower epidermis. The first signs of congestion were scattered, minute, translucent pinpricks, suggestive of stomatal penetration. With continued spraying these enlarged and coalesced to give extensive continuous areas of congested leaf tissue. The time taken to reach this stage depended on the pressure of impact of the spray. With the nozzle held approximately 4 inches from the leaf surface, for example, congestion was complete in a few seconds, but the process took longer at distances from 6–12 inches.

On each variety one branch, consisting of several consecutive fruiting spurs, was treated by one or other of the following methods :—

A. Sprayed with water under pressure.
B. Sprayed with *dilute* inoculum under pressure.
C. Sprayed with *concentrated* inoculum misted on to the leaf surface from a glass throat spray.
D. No treatment.

The concentration of the suspension in C was ×66 that of B, but the volumes of suspension used

in these treatments were so adjusted that the total number of bacteria applied per leaf was approximately the same in both cases. Inoculations were made outside the greenhouse at 11 a.m., the weather at the time being sunny with a light breeze from the south. After treatment the branches were enclosed in polythene sleeves for 30 minutes, and after a further 20 minutes, when all signs of water congestion had disappeared from the leaves, the trees were returned to the greenhouse.

Water congestion itself (treatment A) caused no damage to the leaves (Fig. 4). On branches sprayed with inoculum (treatments B and C) signs of infection were detected three days later as water soaked areas on the undersides of the leaves. These gradually became necrotic and in the next few days spread through to the upper surface. At this stage discrete leaf spots were visible as minute necrotic pin-pricks surrounded by a wider yellow ' halo '. The time taken from infection to the full development of disease symptoms was approximately three weeks ; this period agreed with that estimated for the epidemic. Lesions were also observed on petioles, pedicels, peduncles, and fruitlets, particularly in treatment B. Four weeks after inoculation some yellowing and abscission of leaves was observed on branches of Roundel treated with inoculum under pressure (treatment B). This was eventually traced to the infection of the current and previous year's growth of the fruiting spurs. In the former case there was occasional direct infection of the green spur axis, but in most cases infection had apparently spread into the spur from the base of diseased petioles. The previous year's spur growth is covered by a thick periderm ; infection of this was always indirect from diseased flower peduncles.

The distribution of leaf and spur infections was recorded five weeks after inoculation. Infected leaves were graded into 3 categories according to disease severity, as follows :—

Grade I 1–20 discrete bacterial spots.
Grade II >20 discrete bacterial spots.
Grade III Extensive superficial or marginal leaf necrosis (Fig. 4).

To uninfected leaves, and to grades I, II, and III infected leaves, arbitrary disease ratings of 0, 1, 2, and 3 respectively were assigned. For each treatment the *mean disease ratings* were then calculated. These, together with the percentage of leaves in each grade and the percentage of diseased spurs, are shown in Table I. The untreated controls (D) remained free from infection and are not included.

TABLE I

DISTRIBUTION OF DISEASED LEAVES AND SPURS RESULTING FROM VARIOUS INOCULATION TREATMENTS

Variety	Treatment	Diseased leaves					Percentage diseased spurs
		Percentage				Mean disease rating	
		Grade I	Grade II	Grade III	Total		
Roundel	Water under pressure (A) (31 : 202)*	14·3	1·5	0·0	15·8	0·17	3·3
	Inoculum under pressure (B) (32 : 202)*	18·8	34·1	43·6	96·5	2·18	50·0
	Inoculum from throat spray (C) (23 : 132)*	36·3	37·9	0·0	74·2	1·12	0·0
Napoleon	Water under pressure (A) (8 : 50)*	26·0	6·0	0·0	32·0	0·38	0·0
	Inoculum under pressure (B) (13 : 76)*	29·0	25·0	44·7	98·7	2·13	7·7
	Inoculum from throat spray (C) (9 : 56)*	35·7	50·0	0·0	85·7	1·36	0·0

* Figures in parenthesis refer to the numbers of treated spurs and leaves respectively.

It will be observed from the *mean disease ratings* that the scale of leaf infection on both varieties was most severe where the inoculum was applied under pressure (B). This was due to the occurrence, in treatment B only, of extensive marginal and superficial necroses and to some extent also, to the higher total percentage of leaves infected. The leaf infection on branches sprayed with sterile water under pressure (A), was attributed to natural inoculum originating from overwintered canker infections present on the experimental trees.

In paraffin sections of leaf material from Napoleon (treatment B), fixed three days after

inoculation, bacteria were still mainly confined to the mesophyll tissues in the lower part of the leaf. The lower epidermis was still continuous and the bacteria concentrated under the stomata (Fig. 5). These observations, together with those on water-logging, indicated penetration of the leaves through the stomata.

From the distribution of diseased spurs it was clear that pressure was the important factor in this type of infection. Rapid wilting of the fruiting spurs comparable to that in the epidemic was not observed, suggesting that some additional factor, not operative in the experiment, was involved in 1953. The nature of this is uncertain, but by analogy with Shoot Wilt, which has only been reproduced with difficulty under experimental conditions (Wormald, 1930 ; Crosse, 1953) it may have been related to some inherent condition, e.g., succulence, of the spur tissues.

The results of the experiment support the conclusion that in 1953, driving rain, in addition to dispersing inoculum through the trees, favoured the entrance of bacteria into leaves, petioles, and other organs bearing stomata.

Host infectibility

As already noted, the epidemic was most severe on early flowering cherry varieties and least severe on the late ones. From the distribution of the disease on varieties in general it was evident that severity was related to stage of leaf and flower development and not to inherent resistance of the tissues. The results of the experiment, while not conclusive, support this view. Thus on Roundel, a variety normally of high resistance to all forms of bacterial infection, the leaf disease resulting from inoculum under pressure was equal in severity to that on the low resistant Napoleon, while the spur disease was outstandingly more severe on Roundel than on Napoleon (Table I). At the time of inoculation Napoleon was still at the 60 per cent petal-fall stage, but Roundel had reached the same stage of development, i.e., petal-fall, as the variety Early Rivers had at the time of infection in 1953.

The outstanding severity of the epidemic on Early Rivers was probably due to the fact that the infection conditions described above coincided with a period when the leaves and spurs of the variety were most liable to infection. Late flowering varieties such as Bradbourne Black, normally showing little resistance to leaf infection, probably escaped because the leaves, fruits, and young spur axes were insufficiently exposed, or because they had not reached a stage of development at which they were liable to infection.

Control

Of twelve outbreaks investigated none of the orchards in question had a long history of spraying against Bacterial Canker and Leaf Spot. Where the recommended spring spray (6 : 9 : 100 Bordeaux mixture at white bud) had been used, this failed to control either the Leaf Spot or Spur Wilt. Evidence from one orchard which received a petal-fall spray of Bordeaux mixture for the first time in 1953 suggests that this controlled the disease, the only affected tree being one left unsprayed because of its proximity to a cabbage patch.

Trees of Early Rivers in a mature orchard at East Malling Research Station remained almost free of infection, while trees of the same variety and of comparable age in commercial orchards in the immediate vicinity were badly affected. Since only the recommended white-bud spray was used at the Research Station, the absence of the disease may possibly be explained by a scarcity of spring inoculum resulting from the cumulative control of overwintered canker infections by regular and efficient lance spraying of the trees with home-made Bordeaux mixture in the spring and autumn over a period of nine years.

Acknowledgments

I am deeply indebted to Mr. T. Laflin, N.A.A.S., who provided much information on the varietal distribution of the disease and on the spray histories of commercial orchards ; also to Mr. B. S. Brook for assistance with the experimental work.

Summary

An epidemic outbreak of Bacterial Leaf Spot and Spur Wilt of cherry (*Pseudomonas morsprunorum*), occurring in the spring of 1953, is described. The epidemic was attributed to a prolonged period of wind-driven rain at the end of the flowering period of the early cherry varieties. Experimental evidence suggests that, in addition to dispersing inoculum, the wind-driven rain may have favoured the penetration of bacteria into leaves, petioles, and other organs bearing stomata.

The disease was more severe on the early flowering varieties than on the later ones. Reasons for this are discussed and control measures briefly considered.

Fig. 1.

Leaf Spot of cherry. The tattered appearance of the leaves is due to the falling out of large necrotic areas of leaf tissue. Note the lesion on the axis of the current year's spur growth (indicated by the arrow).

Fig. 2.

Lesion on current year's spur growth. The leaves subtending two of the buds have abscissed.

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FIG. 3.

Spur Wilt of cherry on the variety Early Rivers. Note the brown withered leaves on diseased spurs.

FIG. 4.

Leaves of Napoleon cherry 5 days after spraying : *right*, with water under pressure (treatment A), and *left*, with inoculum under pressure (treatment B). Extensive necrotic areas have appeared on leaves sprayed with inoculum ; at this stage discrete leaf spots are not yet visible.

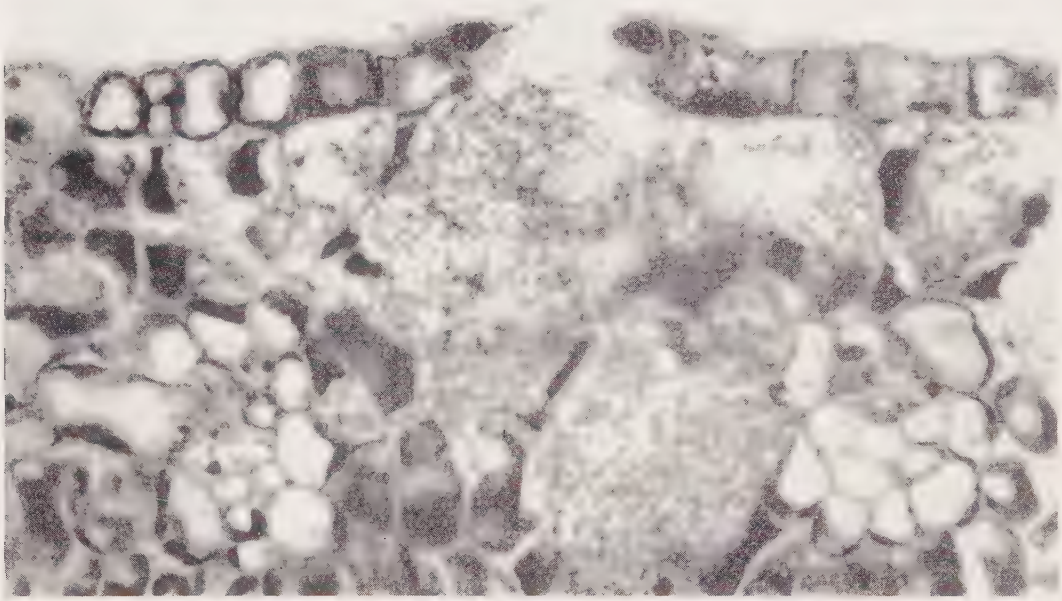

FIG. 5.

Transverse section of a leaf of Napoleon cherry, 3 days after treatment with inoculum under pressure, showing a stoma in the lower epidermis. Note extensive bacterial growth in the substomatal region of the mesophyll. (Stained with Heidenhain's haematoxylin and counter stained with orange G.)

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A STUDY OF WILT-TOLERANCE IN THE HOP BY MEANS OF INTERVARIETAL GRAFT COMPLEXES

By P. W. TALBOYS and J. F. WILSON

It has been shown by Keyworth (1953) that in the hop the qualities of sensitivity and tolerance to Verticillium Wilt are determined primarily by the root system.

Stems of both tolerant and sensitive varieties, grafted to root systems of a sensitive variety, developed acute symptoms when infected from the soil by a highly pathogenic (' progressive ') isolate of *Verticillium albo-atrum*. Similarly, both developed mild symptoms when the infected root system was of a tolerant variety. Thus in respect of Wilt-tolerance the root system appeared to confer upon the stem its own inherent varietal characteristic.

In considering the mechanism of this action, and taking into account the results of various stem-inoculation experiments, Keyworth concluded that there is probably no transfer of a ' resistance factor ' upwards from ' tolerant ' roots, but that the stems of all varieties are equally and highly ' resistant ' to *Verticillium* infection. If this were the case, extensive stem invasion and acute symptom development on ' sensitive ' root systems could result either from a lowering of stem resistance by root impairment or by diffusion of fungal toxins, or from an increase in the invasive power of the pathogen through the establishment of a ' food-base ' or the production of a ' fungal accelerator '.

The experiments to be described were made to obtain further evidence about the possible translocation from non-infected roots of substances having stimulatory or inhibitory actions on the growth of the pathogen or on the resistance mechanisms of the stem.

Experimental methods

Hop plants of the varieties Fuggle (Wilt sensitive) and Keyworth's Midseason (Syn. OR/55, Wilt tolerant) were grown in 7-inch pots in a greenhouse.

In the main series of experiments the plants were allowed to grow to a height of 18–24 in. and were then grafted in pairs of similar or different varieties by means of a simple approach graft, as shown in Figs. 1 and 2. The stem of one of the plants was thus brought into direct vascular contact with two root systems, and it was regarded as the ' experimental ' stem. Similarly, one root system of each combination was able directly to receive downwardly-translocated substances originating in two separate stems. However, the results obtained by Keyworth suggested that such substances would be unlikely to have a determinative effect on root sensitivity and disease expression, and this was confirmed by the present experiments. For the sake of simplicity, therefore, only the evidence relating to direct *upward* translocation will be discussed.

A top graft was applied to a number of plants and allowed to become established before making the approach graft, thus providing a stem of a variety different from both root systems, e.g., Fuggle stem over two sets of OR/55 roots (No. 6, Fig. 2).

In a subsidiary group of experiments, young plants a few inches high were top-grafted with scions of the alternative variety and each allowed to grow through the base of a whale-hide pot. The pot was later filled with a peat and sand mixture to induce the development of an extensive adventitious root system on the scion. By this method the conducting elements of the two components of the graft were joined over their whole cross-sectional area, as opposed to the one-sided junction resulting from an approach graft. The root systems of the two components were, however, at very different stages of development.

After satisfactory establishment of the grafts, certain of the root systems were inoculated by means of finely chopped hop-bine infected with a highly pathogenic strain of *Verticillium albo-atrum*. This was inserted into small holes made in the compost at three points around the circumference of the pot.

Passage of *Verticillium* upwards through the grafts to the experimental stems appeared to be quite unimpeded, and inoculation could be accomplished satisfactorily through either root system.

Symptom records were taken at intervals from June to early September.

Approach-graft experiments

(a) *Tests for a ' resistance factor ' in OR/55.*—The graft complexes (1)–(4), shown diagrammatically in Fig. 1, were used to determine the effects of healthy ' sensitive ' and ' tolerant ' root systems on disease development in stems of both varieties inoculated through a ' *sensitive* ' root system. Severe symptoms and death occurred in all five plants in each treatment, indicating that roots of a tolerant

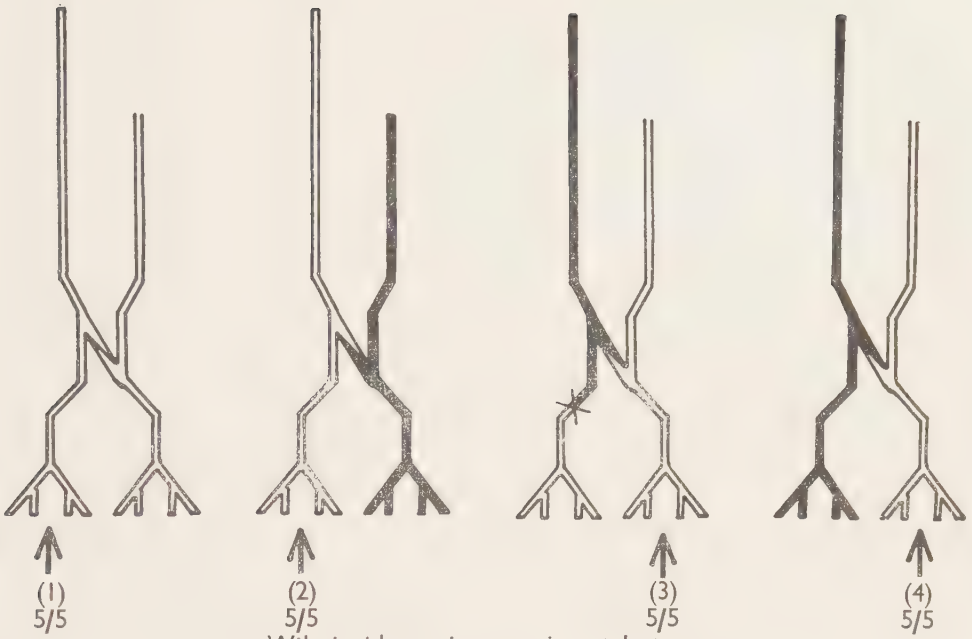

FIG. 1.

Diagram of graft combinations to test for a ' resistance factor ' translocated from ' tolerant ' roots. Open lines represent the sensitive variety Fuggle. Solid lines represent the tolerant variety OR/55. Arrows indicate site of inoculation. Wilt incidence is expressed as No. of experimental bines developing Wilt/No. of combinations inoculated.

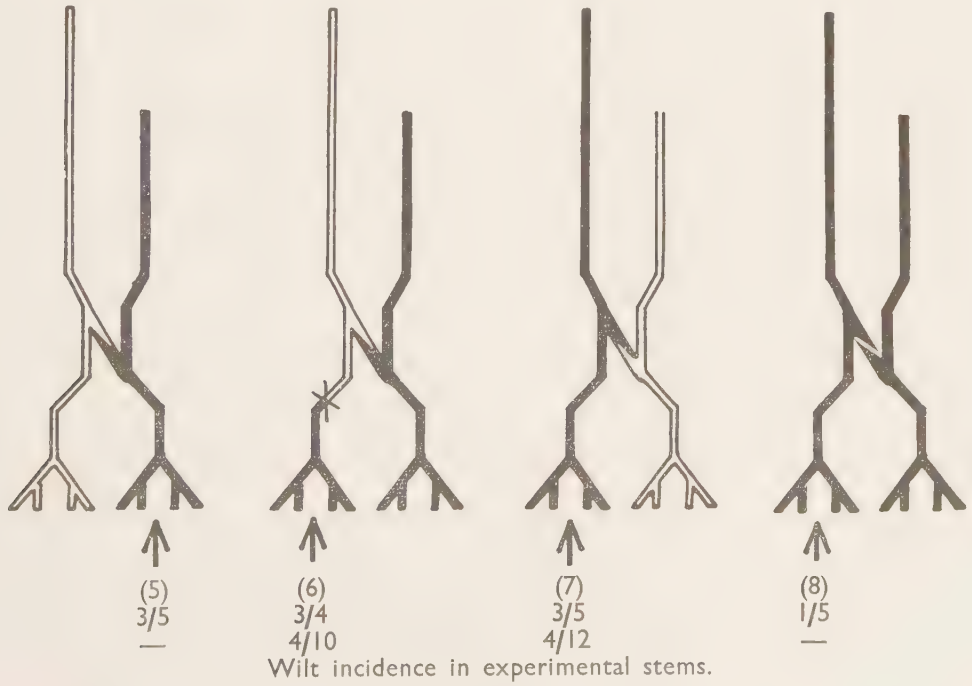

FIG. 2.

Diagram of graft combinations to test for a ' sensitizing factor ' translocated from ' sensitive ' roots. Key as for Fig. 1.

variety probably do not exert a ' protective ' influence on the aerial parts by translocation of substances inhibiting the fungus, nor by stimulating ' resistance mechanisms ' in the stem.

(b) *Tests for a ' sensitizing factor ' in Fuggle.*—The graft combinations (5)–(8) in Fig. 2 showed in a similar manner the influence of healthy ' sensitive ' and ' tolerant ' roots on the development of the disease from an infected ' tolerant ' root system. The results of the 1953 experiments were somewhat inconclusive, but tended to show that when the stem and/or the non-inoculated root system were of the sensitive Fuggle variety the disease incidence was increased. It was found, however, that in groups (5) and (7) a further factor was involved, *viz.*, growth of the pathogen downwards from the graft towards the Fuggle root system, extensive infection being found at soil level. This situation was not apparent in group (6) where both sets of roots were of the tolerant OR/55 variety.

In a limited experiment in 1954 the groups (6) and (7) were set up again in larger numbers, and on this occasion only 4/10 plants in (6) and 4/12 in (7) developed acute symptoms. Downward growth of *Verticillium* was again associated with wilting in (7) but was not detected in (6).

It may be noted that under conditions of very heavy soil infection an appreciable proportion of plants of a tolerant variety may occasionally develop acute symptoms.

Taken as a whole the evidence indicates that there is probably no upward translocation of a fungal accelerator or ' sensitizing factor ' from roots of sensitive varieties.

(c) *Tests of root impairment as a factor in wilting.*—It is commonly observed that infection of plants of sensitive varieties with highly pathogenic strains of *Verticillium* results in a very marked impairment of the root system, whereas in tolerant varieties the effect is generally slight. This was noted by Keyworth (1953) in grafted plants. Such a reduction in the water-absorbing capacity of the plant may be a primary cause of death.

The effect on the grafted plants of root impairment alone was indicated by the non-inoculated groups (9) and (10), Fig. 3, in which one root system was completely severed from the fully grown plant. No wilting or other visible physiological disturbance was evident in either stem of any of the plants treated in this way. It seems improbable, therefore, that death of any of the infected plants in groups (1) to (8) was directly associated with attenuation of the inoculated root system, though the possibility is not excluded that a small water deficit, insufficient by itself to cause wilting, might induce physiological changes resulting in increased sensitivity to fungal invasion.

Top-graft experiments

The graft complexes (11) to (14) used in these experiments are indicated diagrammatically in Fig. 4. Inoculations were made either through the main root system of the stock or through the adventitious roots of the scion.

Infection of ' sensitive ' roots, either of the stock (11) or of the scion (12) led in all cases to death of the plant : ' tolerant ' roots above or below the site of inoculation gave no protection to the plant as a whole.

In group (13), with inoculation through ' tolerant ' adventitious roots, none of the plants developed acute symptoms ; there was apparently no ' sensitizing ' factor moving upwards from the ' sensitive ' roots below. In group (14), however, inoculated through roots of a ' tolerant ' stock, all plants were killed. This was associated with growth of *Verticillium* outwards into the ' sensitive ' adventitious roots.

This graft combination was tested again in the following year, with the lowest adventitious roots developed at 4 in., 9 in., or 20 in. above the graft. At 4 in. 2/6 plants wilted, at 9 in. 1/4 wilted, and at 20 in. none of the six plants developed disease symptoms. *Verticillium* was identified in the adventitious roots of plants which had shown marked symptoms and was apparently absent from comparable roots in non-wilted plants.

Discussion

The results of these experiments are consistent with the evidence of Keyworth (1953), and Heinze and Andrus (1945) that in the Wilt diseases of the hop and the tomato the intensity of symptoms expressed by the plant as a whole depends primarily on some inherent varietal characteristic (or characteristics) of the root system. They show that this is not associated with a general translocation of specific substances from uninfected roots to the aerial parts of the stem. It appears that the entry of a highly pathogenic strain of the fungus into the roots of a sensitive variety, by any pathway, creates conditions under which acute symptoms tend to develop.

Experiments of this kind show that the nature of these vascular wilt diseases is such that, by the time visual symptoms have developed in the aerial parts of the plant, the disease has progressed beyond the stage at which the factors determining the intensity of symptoms are operative.

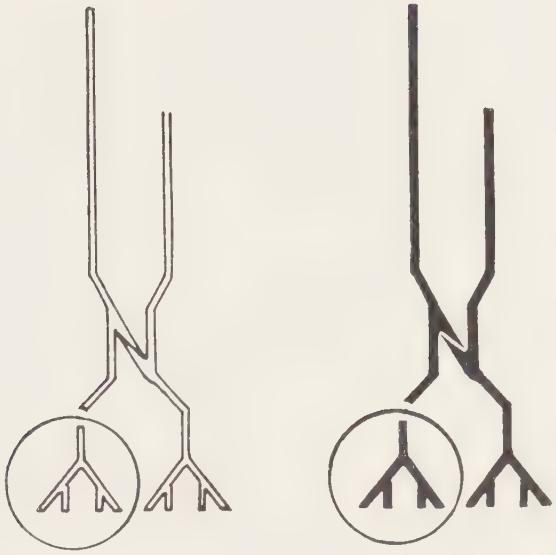

Fig. 3.

Diagram of non-inoculated graft combinations to test the effect of root impairment. Key as for Fig. 1. Circle denotes the severed root system.

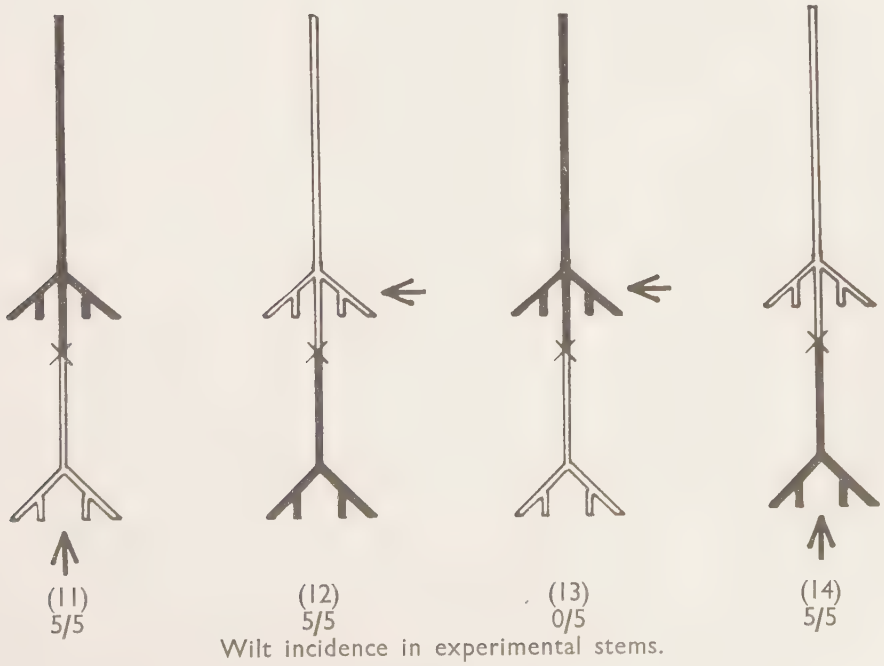

Fig. 4

Diagram of top-graft complexes with adventitious roots developed on the scions, for tests for ' resistance ' and ' sensitizing ' factors. Key as for Fig. 1.

Fundamental work on wilt diseases has mainly been concerned with the processes leading *immediately* to symptom expression, i.e., with the toxic or obstructive actions by means of which the pathogen *within the vascular system* causes desiccation and death of the leaves and stem.

Such pre-supposition of considerable vascular infection may however be somewhat misleading, for that is merely the final stage in a complex sequence of events, including the colonization by the pathogen of the root surface, its penetration of epidermal, cortical, endodermal, and pericyclic tissues, and its entry into the xylem elements of the root.

The host-parasite relationship is likely to vary at all stages in the process according to the inherent characteristics of both host and pathogen, and under the influence of changing environmental conditions.

It seems probable, therefore, that to achieve a reasonably complete understanding of the mechanisms of host tolerance and fungal pathogenicity, it is necessary to study in detail not only the physiological activities of the pathogen in the vascular system of the stem, but also the processes by which such vascular infection is initially established.

Summary

In experiments to supplement earlier work on host-parasite relations by grafting methods, it has been shown that the action of the hop root-system in determining the severity of Verticillium Wilt symptoms does not result from the translocation of specific ' resistance ' or ' sensitivity ' factors.

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ENTOMOLOGY

NOTES ON SOME INTERESTING INSECTS OBSERVED IN 1955

By A. M. MASSEE

1. Raspberry Beetle (*Byturus tomentosus* F.)

A few years ago the Raspberry Beetle was considered the most harmful pest of raspberry and loganberry, but it has not been very common in commercial raspberry fields for several years until this season. It was common in Kent in June and July, and heavy infestations were noted near Brenchley, East Malling, and Maidstone.

It has been the practice of raspberry growers for many years to control Raspberry Beetle by applying a derris dust during the blossom period, or when the fruit is beginning to set. The treatment proved so effective that the beetle populations have steadily declined year by year. In consequence many growers have not dusted their raspberry fields for two or three seasons, thus allowing the populations of beetle to build up again, and this season much harm was caused to the fruits before the grower was aware the beetle was present.

DDT and BHC are sometimes recommended for beetle control. Both are effective, but they should not be used because of the risk of building-up Red Spider Mite populations, especially during periods of hot, dry weather.

2. Green Pug Moth (*Chloroclystis rectangulata* L.)

A severe infestation of the Green Pug Moth was seen in a Conference pear plantation near Chelmsford, Essex, at the end of April. The larvae of the moth were feeding on the opening blossoms and stamens, disfiguring many of the flower trusses. The larvae move from one truss to another in search of food, so that a single larva may destroy a number of blossoms.

This delicate little moth, once regarded as a minor apple pest, is rarely noted in well sprayed orchards today. At the end of April a few larvae were seen feeding on cherry blossoms at Bobbing, Kent, but the numbers were not enough to cause appreciable harm.

3. Cherry Fruit Moth (*Argyresthia curvella* L.)

A severe infestation of the Cherry Fruit Moth was noted in an old cherry orchard, of mixed varieties, at Loose, Kent.

During the latter part of March and early April, the minute larvae which had overwintered on the trees, were observed boring their way into the unopened cherry buds. At this period of the year the larvae are very active and soon eat their way through the bud scales and feed on the tissue inside. During the blossom period the minute, pale, yellowish-green larvae were observed feeding on the petals, stamens and styles of the flowers, and as soon as the fruitlets were formed the larvae tunnelled inside them. In July the pretty little moths were seen in numbers resting on the tree trunks.

The moths proved to be equally common on cherry trees in private gardens adjoining the commercial orchard, and since the trees in the gardens are never sprayed, the problem of the control of the pest in the commercial orchard is very real, and only partial success has so far been obtained.

4. Ghost Swift Moth (*Hepialus humuli* L.)

The larvae of this moth were found tunnelling in the stems at the base of the bines, and feeding on the young fibrous roots of seven-year-old hops at Marden, Kent, at the beginning of June.

The attack occurred on a large area of the garden, and the injury was considerable. The first symptoms of attack were weak growth of the hills, lack of vigour of laterals, and an unnaturally pale colour of the foliage.

The Ghost Moth larvae frequently cause serious harm to hops, and care should be taken to prevent populations building up by applying $3\frac{1}{2}$ per cent BHC dust at the rate of $1\frac{1}{2}$-$2\frac{1}{2}$ cwt. per acre. The chemical should be broadcast around the hills at the end of April, and carefully worked into the soil.

The larva of this pest is also very partial to strawberry, and frequently causes harm by feeding on the roots. This insect was found feeding on the roots of Royal Sovereign strawberry, at Stone Street, near Sevenoaks, in June, but the attack was not very serious. It is not possible to use BHC in fruiting strawberry beds because of the risk of taint to the fruits. Instead crude naphthalene should be worked into the soil, at the rate of 2 oz. per square yard about the middle of April.

5. Summer Fruit Tortricid (*Adoxophyes orana* F.R.)

The Summer Fruit Tortricid was first recorded in this country five years ago, at Teynham. Since then it has been found in fruit orchards from the Medway estuary to the east coast of Kent at Sandwich. It occurs also in other parts of the country near the coast, and there is an authentic record of its presence in Essex, but the number of moths found has not been large.

The Summer Fruit Tortricid has now reached the Weald of Kent, and it is plentiful in some orchards in the Marden district. In this area it is chiefly found on early varieties and Beauty of Bath, James Grieve, and Early Victoria are very subject to attack. The larva has also been found on Conference pear but the injury was slight.

Fruit growers in the Weald are advised to watch carefully for this pest, since it can cause considerable injury to comparatively large fruits once it has become established in an orchard. The larvae are not easy to find, even when they are feeding on the fruits in July and August, because of their habit of attaching a leaf to the apple surface, and feeding between the leaf and the fruit in protected situations. Another favourite site where the larvae feed is where two or three fruits touch, and in such positions they are very difficult to detect.

This pest has been reported from orchards in the Horsmonden district, but at present only a few larvae have been found.

6. Apple Fruit Moth (*Argyresthia conjugella* Zell.)

Larvae of the Apple Fruit Moth were found tunnelling in the fruitlets in several varieties of apple, in a number of orchards in the Ash district, near Sandwich, Kent, in July. The moth appeared to be well established in the area, and it is possible that it has been breeding there for a number of years. Last year it was reported from three new localities in Kent, namely, West Peckham, Horsmonden and Sevenoaks, and its occurrence at Ash this year suggests that it is still extending its range in the county.

7. Common Gooseberry Sawfly (*Pteronidea ribesii* Scop.)

A number of insects associated with fruit behave in an unusual manner, for instance, their populations stay at a very low level for a number of years, and although they are frequently present in the plantation, they are not regarded as important, and control measures are not necessary. Then suddenly the populations increase, and the insect becomes a potential pest.

One such insect is the Common Gooseberry Sawfly. The first generation was very numerous on several varieties of gooseberry during the second week of April in many parts of Kent, and at Chelmsford, Essex. In a gooseberry field at East Malling, the larvae of the first generation were not noted, but those of the second were abundant at the end of June.

The larvae are voracious feeders, and the bushes may be largely defoliated in a very few days. In fact defoliation often occurs before the grower is aware of the presence of the insect.

8. Apple Leaf Hopper (*Typhlocyba froggatti* Baker)

One of the commonest species of leaf hopper on apple, *Typhlocyba froggatti* Baker, is once more becoming prevalent in Kentish orchards, and large infestations were noted at East Malling, Horsmonden, Plaxtol, and Sutton Valence from early June until the end of the summer.

It may be recalled that this leaf hopper used to be very common, but largely disappeared from commercial orchards following the modifications of the spray programme after the war. It is not clear why the leaf hopper populations are building up again in many Kentish orchards, but the modern trends of applying chemicals by low volume mobile machines may be one of the reasons.

The leaf hopper is also much more prevalent on plum this season, but at present it does not seem to be common on pear.

9. Pear Sucker (*Psylla pyricola* Föer.)

High populations of Pear Sucker eggs were observed in plantations at Sittingbourne, Faversham, Lynsted, and Maidstone during the last week of April. The insect was also reported from several localities in Worcestershire at the same period.

The overwintering females were not found commonly on the pear trees during the winter of 1954-5, but judging by the large number of eggs deposited on the buds and spurs in early May, large numbers of them returned to the trees from other hibernating quarters.

10. A species of thrips feeding on Apple foliage

A species of thrips causing characteristic injury to apple foliage and shoots was reported from Bridge, near Canterbury, Kent, during the middle of July. The thrips were first seen on Golden Delicious apples, planted as maidens six years ago. A Cox's Orange Pippin orchard adjoining was also infested to a lesser extent.

The thrips mainly fed upon terminal leaves of new growths, causing leaves and stems to turn brown and become distorted. The more severely infested leaves were characterized by leaf skeletonizing and a lace-work pattern of the upper surface, together with an inward and upward twisting of the young foliage. Superficially the damage is very similar to that caused by the Gall Mite, *Vasates schlechtendali* Nalepa. At present the species of thrips concerned has not been determined.

Two species of thrips are recognized on apple and pear in this country. They cause a slight discoloration of the young leaves, but are not regarded as being very troublesome.

The writer is indebted to Mr. P. G. Clark for bringing this interesting insect to his notice.

11. Cherry Black Fly (*Myzus cerasi* F.)

In common with many other species of fruit aphids the Cherry Black Fly was abundant in cherry orchards in many parts of Kent during the spring and summer months. Particularly bad infestations were noted at East Malling, West Farleigh, and in east and mid Kent. Early Rivers and Early Amber were often heavily infested, but many other varieties suffered considerably.

Small colonies of aphids were noted on the young growths in late April and May, in spite of the use of winter and spring insecticides. It is very difficult to spray an established cherry orchard thoroughly, so that probably some of the aphids escaped. By the middle of June large colonies of aphids were present on new shoots and leaf curl was severe. On badly infested trees the honeydew produced by the aphids made the leaves and fruits sticky—the result being small and poor fruits.

In a normal season it is usual for some of the aphids to remain on cherry most of the summer, but the majority migrate to their summer hosts, e.g., bedstraw, etc., returning to cherry in the autumn. This season proved exceptional since most of the aphids remained on cherry all the summer, causing considerable injury to the trees.

Many years ago the Cherry Black Fly was regarded as the most important cherry pest, but nowadays it is rarely troublesome.

12. Oat-Apple Aphid (*Rhopalosiphum insertum* Wlk.)

The Oat-Apple Aphid was more prevalent in the spring months than for many years past. Severe infestations were common in Kent, Essex, and Sussex, and in most other fruitgrowing counties.

The peak of hatching occurred during the first week of April, when large numbers of aphids were clustered around the tips of the buds. The Easter holidays came when spraying operations should have been in full swing, and the interruption of the routine sprays allowed large colonies of aphids to build up. However, effective control was obtained in orchards where 0·1 per cent DDT emulsion was applied *thoroughly* at the bud-burst to mouse-ear stage. In many orchards large populations of the Oat-Apple Aphid built up and severe leaf curl resulted. In most cases such orchards had been sprayed by improvised mobile machines, and the lack of control could be explained by the poor cover obtained.

In some cases poor aphid control was obtained when the spraying was done by means of the autoblast and low volume machines. One of the chief reasons for failure was that the machines were driven too fast to allow the spray to drift through the orchards and wet the shoots adequately, particularly those at the tops of standard trees.

In most seasons two generations of the Oat-Apple Aphid breed on apple in the spring, after this winged forms are produced and these migrate to wild grasses for the summer months. This year, however, three and even four generations of aphids bred on apple before dispersing to their wild summer hosts. In some areas colonies of aphids persisted until early July, and leaf-curling was prevalent in most orchards.

13. Bryobia Mite (*Bryobia praetiosa* Koch)

Several forms or races of the Bryobia Mite are recognized, each with its own peculiar life cycle and host associations. The wall form or race hibernates in the adult state in dwelling houses, barns,

cracks and crevices in walls, etc. This mite was very common in the autumn of 1954, a large number of houses near Maidstone and East Malling being invaded. Generally speaking the mites were not troublesome during the autumn and winter months, since they went into hibernation, selecting any crack or crevice away from the direct sunlight. In a few overheated rooms the mites were active from time to time during the winter.

The mites came out of hibernation during the second and third weeks of April, and were present in tens of thousands on the walls, windows and ceilings of many of the rooms. Some cottages near East Malling were so heavily infested with mites that considerable annoyance was caused to householders.

It was not possible to kill the mites by spraying with an acaricide, but they soon dispersed into the open when all the windows and doors were left open on all possible occasions, especially on warm, sunny days.

14. Phytoptid mite on cherry

Damage of an unusual nature was caused to the leaves of Gaucher Cherry by the Gall Mite, *Vasates fockeui* Nal. and Trt. at Bobbing, Kent, in May.

The mites pass the winter under the bud scales and inside the buds, where they feed on the inner tissues. The injured areas being plainly visible when the buds open and the leaves expand. The feeding areas are brown in colour and numerous little splits occur in the tissue. These leaf symptoms have been noted for many years, but the cause of the damage was not known until this year.

The variety Gaucher is very subject to injury, but several other varieties including Early Rivers, are attacked to a lesser extent.

Summary

Brief accounts are given of some of the interesting insects and mites observed in 1955. Amongst the more interesting are the Raspberry Beetle, Cherry Fruit Moth, Apple Leaf Hopper, Apple Thrips, Oat-Apple Aphid, and the Bryobia Mite.

SOME TETRANYCHID MITES ON FRUIT TREES

By ELSIE COLLYER and JOAN R. GROVES

The commonest Tetranychid mite found in the commercial orchards of Essex and Kent is the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch), which has been studied in detail by Blair and Groves (1952). Recently Collyer (1953) has recorded the Greenhouse Red Spider Mite, *Tetranychus telarius* L. (=*urticae* Koch), as appearing in gradually increasing numbers in certain Essex orchards where parathion had been used as an acaricide. Several other species of Tetranychids are also seen on fruit trees especially where the latter are unsprayed. Of these *Bryobia praetiosa* Koch is well-known on apple trees (Massee, 1954), and *Brevipalpus geisenheyneri* (Rübs.) (=*Tenuipalpus glaber* Donn.), popularly known as the Flat Scarlet Mite, has also been known on apple for many years (Massee, 1932). *Eotetranychus carpini* Oudms. and *Tetranychus crataegi* Hirst are less common and the life-histories of these species and of *B. geisenheyneri* in England are described here for the first time.

Other phytophagous and some predacious species are also found on the leaves of fruit trees, but none of these is normally found in conspicuous colonies ; the Tetranychids are seen either in close colonies covered with webbing, or they live freely without webbing but aggregate together.

Tetranychus crataegi Hirst

This species, also known as *T. viennensis* Zacher, was previously recorded in Buckinghamshire on Aylesbury Prune (Massee, 1944), but only recently has it been found in Essex and Kent. At East Malling it has occurred for several seasons on unsprayed cordon pears grown on a wall, and also on unsprayed apple trees in gardens and orchards in the neighbourhood. In Essex it has been found in isolated colonies on unsprayed apple trees. Rambier (1954) described it in southern France, where it has occurred in recent years in sufficient numbers to cause damage to the foliage of various fruit trees, particularly apple.

The mites live in very well-defined colonies on the underside of the leaves. The plum-coloured adult females place single strands of webbing over an area often an inch in diameter producing a light canopy. The immature stages and the males feed beneath the shelter of the webbing strands and rarely move away. The eggs are laid in the webbing, well away from the surface of the leaf. New colonies are formed by the females moving to another part of the leaf or to another leaf, and there may be more than one female to a colony. The leaf becomes pale and mottled on the upper surface, indicating the extent of the colony on the other side. The conspicuous plum-red females and the compactness of the lightly webbed colonies of pallid immature mites make this species distinctive, although it is otherwise very similar to *T. telarius*.

Adult.—The morphological characters of the adult mites were described by Hirst (1920) and also by Zacher (1920a and b). The diagnostic feature is the shape of the penis. The adult females of each generation are a distinctive deep plum-red colour with colourless spines, and are about 0·60 mm. in length. The adult male is pale green, and has a much smaller body than the female, measuring only 0·37 mm. in length.

Immature stages.—All the immature stages are very pale green, or sometimes yellowish.

Egg.—The eggs are slightly flattened spheres similar to those of *T. telarius* but slightly larger, averaging 0·17 mm. in diameter. They are almost colourless when first laid, but become pale green later and, just before hatching, turn amber.

Biology.—The mite overwinters as an adult female in sheltered places on the tree. In the middle of May the females start to lay eggs and colonies are formed on the leaves. From 1949 to 1955 observations were made on the life history of this species. The incubation period of the egg varied from 4 days in July to 14 days in April and May. After hatching, females took an average of 17 days, and males 14 days, to mature. In midsummer, each female had a pre-oviposition period of 3 days and laid about 25 eggs (range 18–33) over an average of 16 days (range 10–19). From these figures the mite takes approximately 27 days to complete one generation, and in 1952 and 1955 some passed through five generations.

Hosts.—Colonies of this mite species have been found in south-eastern England on apple, pear, and myrobalan. In addition Hirst (1920) found it on hawthorn, Zacher (1920b) on cherry, sloe and mountain ash, and Rambier (1954) on many fruit trees, including peach. Discoloration of the leaves is caused by the mites feeding, but does not reach the level of economic significance in England. A predator which often attacks *T. crataegi* colonies is the small ladybird, *Stethorus punctillum* Wei.

***Eotetranychus carpini* Oudemans**

The mites live in small, well-defined colonies on the underside of the leaf, forming light patches which are only visible from below. They form an area of compact webbing beneath which all stages of the mite live and feed. Eggs are laid either in this webbing, or beneath it on the leaf surface. When the females mature they move away and form a new colony. On apple trees this species is found most abundantly on varieties where the leaves have a hairy under-surface.

Adult.—The morphological characters of the adult mites were described by Oudemans ; they differ from mites of the genus *Tetranychus* in the presence of an extra pair of dorsal setae, making a total of 13 pairs. The chief diagnostic feature is the shape of the penis. In a booklet recently published by the British Museum (Natural History), Evans and Browning (1955) figure the female of both *E. carpini* and *T. telarius*. Both female and male mites are green in colour and often have small black dots along the body. They are small and inconspicuous, the females being only 0·37 mm. in length (compared with 0·60 mm. for *T. telarius*).

Immature stages.—These are all of a pale green or greenish yellow colour.

Eggs.—The eggs are spherical, about 0·10 mm. in diameter, and considerably smaller than those of *T. telarius* (0·13 mm.). They are very pale green, and do not change colour prior to hatching.

Biology.—The mite overwinters in the adult female stage beneath the bark and in crevices on the tree. These females become active in April when they move on to the leaves and start to lay eggs; there are a number of successive generations through the summer. Observations on the life history made in 1952 showed that the incubation period of the egg varied from 14 days in August to 26 days in September and October, each female laying on an average more than one egg per day. The development period from hatching to adult took from 12 to 18 days, six generations being completed before the overwintering females matured in October.

Hosts.—This mite has been found on apple, bramble and hornbeam (*Carpinus betulus*) in England. In addition, Geijskes (1939) records *Corylus avellana*, *C. maxima* and *Salix caprea*, and Zacher (1920b) oak as hosts. In south-eastern England it has only been found on apple trees where these are unsprayed, and it never causes serious damage. The colonies are frequently attacked by such predators as *Typhlodromus* spp. and Cecidomyid larvae, which live within the webbing made by the mites.

***Brevipalpus geisenheyneri* (Rübs.)**

Baker and Pritchard (1952) consider *B. geisenheyneri* to be the correct name for the species, otherwise known as *Tenuipalpus glaber* Donn., which was recorded by Massee (1932) in England, where it is known as the Flat Scarlet Mite, and also for *Tenuipalpus oudemansi* described by Geijskes (1939) from apple trees in the Netherlands. Dosse (1953) gives an account of *T. oudemansi* in Germany, where the main host plant is also apple. In Egypt it occurs abundantly on a wide range of host plants, and causes economic damage. The Flat Scarlet Mite is very small and is only noticeable because of the intense scarlet colour of the females. It lives on the under surface of leaves, generally alongside the midrib and leaf veins ; it does not form webbing, but is usually found in groups, being typically a sedentary species.

Adult.—The female is bright red, with a rectangular, flattened body, and very short legs. It measures 0·32 mm. long and 0·16 mm. wide. The male is somewhat shorter and paler in colour, its abdomen being almost transparent and curving upwards.

Immature stages.—These are similar to the adult in shape, but somewhat paler in colour.

Egg.—The eggs are bright red, oval in shape, and measure 0·11 mm. × 0·07 mm.

Life history.—The adult females hibernate on the bark of the trees, but they are active early in the spring, wandering on leaves from April onwards, although they do not move completely on to the leaves until some time in May. The first eggs are laid on the wood in late April, but subsequently they are laid on leaves, being placed along the midrib or leaf veins, and usually buried beneath leaf hairs. Egg-laying continues until mid-July, by which time the females all die. Eggs start to hatch at the end of June, and the average incubation time in 1955 was 55 days. The following generation of adults begins to appear at the end of July ; at first there is a preponderance of males, but later approximately equal numbers of males and females. Mating takes place in August and September, after which the males gradually die off leaving only the females to overwinter. There is only one generation a year in this country.

Hosts.—The complete list given by Baker and Pritchard (1952) is : apple, apricot, bramble, cherry, cotoneaster, dogwood, pear, plum, rose, walnut and willow, but, in England, this mite is found only on unsprayed apple trees.

***Bryobia praetiosa* Koch**

These mites are larger than the other species considered here. They are dark red or brown, very conspicuous, and are often seen wandering on the upper surfaces of the leaves. Although they

feed on the leaves, much of their time is spent on the wood of the younger twigs and branches, where moulting takes place, the groups of white moult skins on the wood being characteristic of the species.

Adult.—The females have been illustrated by Evans and Browning (1955). They are dark red or reddish-brown, 0·70 mm. in length, with long legs, the front pair of which are particularly long and mobile resembling antennae. The body is flattened and horny, and bears a number of fan-shaped setae. Males have not been found.

Immature stages.—The nymphs are similar to the adults but are dark red, brown or dark green. The larvae are bright orange-red. All stages have the long front legs.

Eggs.—The globular, dark red eggs of this species are distinguishable from those of the Fruit Tree Red Spider Mite, in both summer and winter, by their larger size, darker colour, and absence of a dorsal spine.

Biology.—B. praetiosa is common on apple, gooseberry, and ivy (*Hedera helix* L.). Recent study has shown that the forms found on these three hosts, although morphologically similar, are distinct biological races, with different life-histories (Mathys, 1954). The following observations refer only to the race found on apple, plum, or damson, a race that spends its complete life on one or other of these hosts. This race overwinters as an egg on the bark, the eggs hatching in early April. The mites feed on the leaves, but usually return to the wood for moulting, the white moult skins on the wood being very conspicuous. In cool weather, also, there is often a migration back to the wood from the leaves. The summer eggs are usually deposited on the wood, although some are found on the petiole and leaf blade. This species does not form webbing. The development is relatively slow ; the incubation period of the summer eggs in 1954 was 24 days in May and June, and 22 days in August, and in 1955 was 22 days in June and 17 days in July and August, and development from hatching to adult took on an average 21 days. There were three complete generations, and a partial fourth, during the season.

B. praetiosa causes leaves to bronze rapidly, and such damage is often seen on apple and gooseberry, particularly in April when the young leaves are only just developing.

Key for separation of some Tetranychid mites on fruit trees

The following key is based on the habits of the mites, and external features which can be seen with the aid of a hand lens.

1.	In webbed colonies	2
	Not in webbed colonies	4
2.	Adult female deep red ; immature mites and males pale green	*Tetranychus crataegi* Hirst
	Adult female green or orange ; immature mites and males pale green or yellow	3
3.	In dense colonies, very small green females	*Eotetranychus carpini* Oudms.
	In less dense colonies with larger green or orange females	*T. telarius* L.
4.	Large mites with long front legs, flattened dorsum, moult skins often on bark	*Bryobia praetiosa* Koch
	Smaller mites with short front legs	5
5.	Medium-sized mites with convex dorsum, all stages of mites and eggs red, moult skins on leaves	*Metatetranychus ulmi* Koch
	Very small mites, flattened dorsum, females bright scarlet	*Brevipalpus geisenheyneri* (Rübs.)

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Summary

An account is given of the occurrence of *Tetranychus crataegi* Hirst, *Eotetranychus carpini* Oudms., *Brevipalpus geisenheyneri* (Rübs.), and *Bryobia praetiosa* Koch on fruit trees in Essex and Kent, with a brief account of their life histories. A key for the separation of six species of Tetranychid mites is included.

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A FURTHER NOTE ON A CAMBIUM MINER OF *PRUNUS* SPP. (*DENDROMYZA CERASIFERAE* KANGAS, AGROMYZIDAE, DIPT.)

By R. S. PITCHER

In the years 1952–54, inclusive, further observations were made on the cambium miner which Lee (1953) found in *Prunus* spp. All stages of the life cycle have now been identified and mature flies bred. Specimens of the latter have been sent to a specialist in the group, Prof. E. Kangas of Finland, who considers them to belong to a new species which he has named *Dendromyza cerasiferae*. As he is publishing a full description of the species (Kangas, 1955) no details of morphology will be included in the present paper. The writer's observations have borne out Lee's suggestion that the life history follows the same general pattern as that of *Agromyza pruni*, Grossenbacher (from *Prunus* spp. in N. America (Grossenbacher, 1915 ; Malloch, 1915)) and *D. aucupariae* Kangas (from *Sorbus aucuparia* in Finland, (Kangas, 1948)) both of whose larvae overwinter in the tree. Most of the other known species, including *Dizygomyza barnesi* Hendel, (from willow in Britain (Barnes, 1933)) and *D. tremulae* Kangas (from birch, willow, and aspen in Finland (Kangas, 1948)) belong to a group whose larvae overwinter in the soil.

Life history

Eggs.—The eggs resemble those of *D. barnesi* in shape and surface texture. In size they range from 0·66×0·20 mm. to 0·83×0·29 mm. ; they are approximately circular in cross section and elliptical in longitudinal section. In an unheated insectary eggs were laid from 27th June to 8th July, 1953, but probably the egg-laying period is more extended in the field. Caged flies, offered cut shoots of one-year-old and current year's wood, laid all their eggs in the former. Eggs were inserted, usually through a lenticel, into the periderm, and lay directly on the phellogen. Usually only one egg was laid through each puncture but groups of up to four did occur. Hatching time is unknown and no eggs were found in the field, but several larval tracks were traced back to oviposition sites comparable to those chosen in the insectary.

Larvae.—The larvae are typical of the genus, being slender, white, and opaque and are furnished with a powerful chitinized mouth-hook and girdles of minute cuticular processes, especially on the posterior segments. When fully fed thay may reach a length of 18 mm. and a breadth of 1 mm. Feeding takes place from July to May in the cambial layer of the host, giving rise to ' pith flecks ' which become incorporated in the wood of the tree (Grossenbacher, 1915). Larval movement is in general downward, although recurrent upward tracks are common. After hatching, the larva loses little time in leaving the one-year wood, and most of the feeding occurs in two to four-year wood. Mining in five-year wood is infrequent. In size the mines correspond closely with the larvae ; those made before the winter, when the larvae are up to 6 mm. long are relatively inconspicuous. In the winter months cambial activity ceases and little or no feeding takes place. In spring the larvae begin to mine vigorously and grow rapidly, nearly trebling their length in six weeks. At least one moult occurs during this period. From mid-May onwards each larva cuts a narrow vertical slit in the bark through which it leaves the tree, usually at night, to pupate in the soil. In 1953 and 1954 most of the larvae had left by early June, the last being recovered on 23rd June. The exit holes, which are mainly in 2 to 4-year wood, soon fill with callus, leaving an ovoid scar one to two mm. long.

Pupae.—Larvae quickly enter the soil, contract, and pupate in a translucent puparium about 4·0×1·5 mm. in which the black mouth-hook is clearly visible. Puparia can be readily recovered from the top inch of soil by sieving and flotation. Individual pupation times are not available, but under insectary conditions 31 days elapsed between the entry of the first larva into the soil and the emergence of the first fly.

Imagines.—Mature flies are slow-moving, black in colour and three to four mm. long. In the insectary they emerged from 20th June to 22nd July, 1953 ; both sexes lived four or five days. The high degree of parasitism encountered severely curtailed breeding work and only two egg series, of 36 and 61 respectively, were secured.

Parasites

The Braconid, *Sympha mandibularis* Ns., appears to be a highly successful parasite of *D. cerasiferae*, 80 per cent of the pupae being affected. This is the more surprising in view of the sheltered

larval habitat. Parasite larvae matured at about the same time as those of the host and pupated within the host puparium, emerging in the insectary from 25th June to 22nd July, 1953. Observation was maintained, without result, on parasites caged on shoots containing newly-laid host eggs. It nevertheless seems probable that the thinly covered eggs or very young larvae are the stage attacked by the female parasite.

Economic importance

As Lee has said, direct injury to the tree by *Dendromyza* is of little importance. The possibility, however, that the mining of the larvae may influence the development of cankers (caused by the bacterium *Pseudomonas mors-prunorum* Wormald) on the stems of young plum trees is being considered in collaboration with Plant Pathology Section.

Achnowledgements

The writer wishes to thank Prof. E. Kangas, Dr. H. F. Barnes, Mr. N. R. Lee, and Miss D. V. Merton for their assistance. The parasite was identified by Mr. G. E. J. Nixon.

Summary

An account is given of all stages of the life history of a cambium miner of *Prunus* spp. *Dendromyza cerasiferae* Kangas. Reference is also made to parasitism and economic importance.

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NOTES ON THE BIOLOGY AND IDENTIFICATION OF SOME ALLIES OF THE WINTER MOTH (*OPEROPHTERA BRUMATA* (L.))*

By J. B. BRIGGS

During a four year study of the Winter Moth at East Malling from 1951 to 1954, some information was also gathered on the biology, and identification, of these Notodontoid moths, sometimes collectively known as ' Winter Moths ', the larvae of which have been reported as damaging fruit trees, by Whitehead (1888), Theobald (1909), Massee (1945, 1946), Sorauer (1953), and others, usually as members of a caterpillar complex with the Winter Moth as the most abundant species :

Hydriomenidae† : *Operophtera fagata* (Scharf.), Northern Winter Moth.

Brephidae : *Alsophila aescularia* (Schiff.), March Moth.

Selidosemidae : *Erannis leucophaeria* (Schiff.), Spring Usher Moth ; *E. progemmaria* (Hb.), Dotted Border Moth ; *E. aurantiaria* (Esper), Scarce Umber Moth ; *E. defoliaria* (Clerck), Mottled Umber Moth ; *Apocheima hispidaria* (Schiff.), Scarce Brindled Beauty Moth ; *Phigalia pilosaria* (Schiff.), Pale Brindled Beauty Moth ; *Theria rupicapraria* (Schiff.), Early Moth.

Adult moths

The adults are active during the colder months of the year. The female moths are peculiar in that the wings are reduced to mere flaps which do not serve as organs of flight. On emergence from their pupal skins in the soil, the females climb the trunk of the tree, usually at night, and lay their eggs on the branches. They are thus likely to be observed on greasebands, or disturbed from the branches by tapping. They are short lived and lay their eggs almost as soon as they are fertilized by the male moths. The length of adult females varies from one to nearly three centimetres according to species. A key for the identification of these apterous females is given in Appendix 1.

The slender male moths, which are active at night, have functional wings, whose span varies from about two to five centimetres according to species. Specimens may be seen on greasebands or resting on tree trunks, fence posts, and stakes during daylight, though the majority remain concealed. After nightfall moths may readily be observed on the wing.

In 1952–54 a Robinson light trap, with a suitable anti-inhibition device (Robinson, 1952), was used to investigate the flight period of the males of these species, while traps on the trunks of standard cherry trees showed the period when females were active. For each species, these periods were broadly similar for both sexes. Fig. 1 indicates the total period, in the three seasons, during which adult moths were observed.

Eggs

The eggs of these species, which are all ovoid in shape, are laid in crevices in the bark, with the exception of those of *Alsophila aescularia* which are laid in a band or partial band around the twigs (Fig. 3). Table I gives some descriptive details which should be studied in conjunction with Fig. 2 ; the details for *Apocheima hispidaria* and *Theria rupicapraria* are quoted from Tonge (1933) as material for study was not available to the present author. The egg measurements for the other species are the means of 25 observations. In the last column are given the earliest and latest months in which eggs may be found.

Larvae

The larvae of these species, in common with the others of the super-family, are distinguished by the absence of prolegs on abdominal segments three, four, and usually five. They travel along the foliage in the familiar manner which has given them the name of ' Looper ' larvae, drawing the prolegs up to the thorax and then extending the latter to a new foothold. From late March to early June they feed on the leaves, and to a lesser extent the blossoms and developing fruitlets, of various fruit trees. Where caterpillar attacks are not controlled the damage they do is usually obscured by the much greater damage done by the caterpillars of the Winter Moth. However, some reports suggest that in occasional absence of the latter, certain of these other species are capable of inflicting quite

* The information contained in this paper forms part of a thesis submitted for the degree of M.Sc.(Hort.) of London University.

† Nomenclature according to Kloet and Hincks (1945).

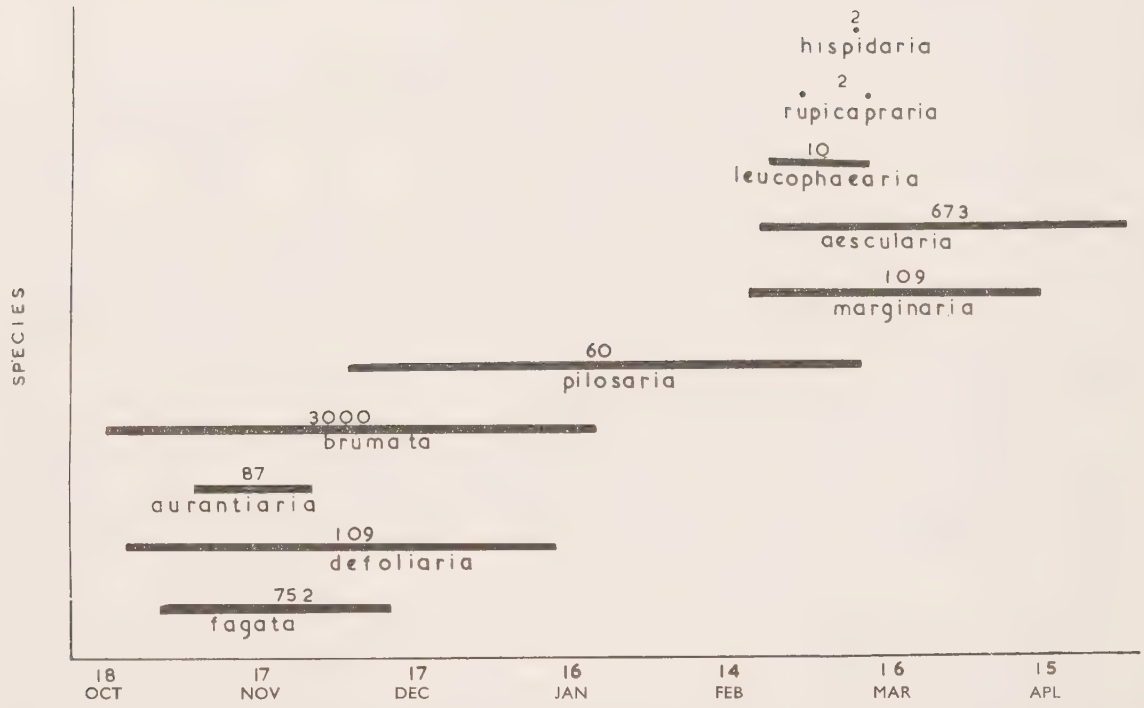

FIG. 1.

Flight period of moths, 1952–54. Numbers above the lines indicate, for each species, the total number of specimens of both sexes taken.

TABLE I

FEATURES OF EGGS OF SOME NOTODONTOIDEA

Species	Egg colour	Markings	Length Means of 25 observations	Width	Months when found
Operophtera brumata	Pale orange	Deep five to six-sided pits	0·61	0·38	Nov.–Apl.
Operophtera fagata	Pale orange	Deep five to six-sided pits	0·74	0·46	Nov.–May
Alsophila aescularia	Brown	In a band, smooth, covered with hairs			Feb.–May
Erannis leucophaearia	Pea green	Longitudinal wavy ridges	0·65	0·40	Feb.–Apl.
Erannis progemmaria	Lime green	Longitudinal rows of rectangular pits	0·68	0·42	Mch–Apl.
Erannis aurantiaria	Orange red to drab green	Bold longitudinal ridges and faint transverse lines	0·80	0·43	Nov.–Apl.
Erannis defoliaria	Straw	Faint transverse ridges	0·88	0·51	Oct.–Apl.
Apocheima hispidaria	Greenish copper		1·10*		
Phigalia pilosaria	Olive brown	Faint reticulation of ridges	0·90	0·54	Dec.–Apl.
Theria rupicapraria	Purplish		0·65*		

* Data from Tonge (1933).

severe damage to the tree. A key to the full-grown larvae is given in Appendix II. To make the key of more general use, various other Notodontoid larvae not referred to in this paper, but sometimes found on fruit trees, are included.

Pupae

All pupate in the soil, either in silken cocoons or as naked pupae.

Biological notes

Operophtera fagata.—The Northern Winter Moth, despite its name, is commonly found in Southern England. Massee (1945) recorded this species from apple and plum, though its usual hosts are birch and beech. Adult moths have been trapped in apple, pear, and cherry orchards, but birch trees were always close at hand. A few larvae have been taken from cherry (Early Rivers) and reared to maturity on that host, while others have been reared to maturity on apple. Thus it seems that this species may support itself on apple and cherry, but is unlikely to be met with in any numbers except in the neighbourhood of birch trees.

The male moth, though similar to that of *O. brumata*, is paler, somewhat larger (wingspan 25-30 mm. as compared with 20–25 mm. for *brumata*), and the hindwings are without the prominent cross lines of the Winter Moth. The winglets of the female moth exceed 3·5 mm. in length and 1·5 mm. in width, with a prominent median band of dark scales. The egg is larger than that of the Winter Moth, but in other respects is similar. The larvae hatch in the last few days of March or early April, and are also very similar to those of the Winter Moth in their early stages. Later, however, the chitinous parts of the larva of *fagata* remain dark, as do the dorsal and spiracular stripes whereas both chitinous parts and stripes become paler in *brumata*. The larvae feed until late May, growing to about 3 cm. in length ; they then descend to the soil and spin a silken cocoon within which they pupate.

Alsophila aescularia.—This species is common on apple, cherry, and plum, though never as abundant as *O. brumata*. The greyish male moth may be recognized by its slender abdomen and the characteristic posture of the forewings at rest, crossed over the abdomen with the inner edges overlapping. The female is pale brown, and before laying eggs has a rather round abdomen with a striking anal tuft of fine shining hairs, which are used to cover the eggs as they are laid. Some hairs usually remain after oviposition is complete, when the spent female may often be found for many days still in attendance upon the egg band. The eggs hatch in from four to eight weeks, from early April to mid-May, and although the young larvae may initially feed together, they soon become dispersed. At this and all later stages they may be distinguished from the larvae of *O. brumata* by the presence of a reduced pair of prolegs on the fifth abdominal segment. The larvae pupate in silken cocoons in the soil in May and June, a few days later than the Winter Moth.

Erannis progemmaria.—This species has not apparently been recorded from fruit trees in the British Isles though Sorauer (1953) records it in orchards in Germany. The author has collected larvae from apple and cherry, and a single female has also been taken from the bark of an isolated plum tree ; it had probably fed on the leaves as a larva. The male moth is dark creamy brown to brown, 30–35 mm. in wingspan, and except in the very darkest specimens has an irregular pale band across the forewings ; these, with the hindwings, have a row of black dots on the apex. The eggs hatch in about a month and the larvae are grey, olive green, or even whitish ; the spiracles are always surrounded with white. The larvae mature in late May and early June ; the pupae in the soil are naked.

Erannis aurantiaria.—This species is recorded from apple, damson, cherry, and nut. The male moth is orange-yellow in colour with two greyish-purple cross lines on the forewings, whose span is from 35–40 mm. The abdomen of the female is longer than that of *O. brumata*, with sufficient yellow scales on the dorsal surface to give a tawny appearance. These scales are slender and two to four pointed ; those on the upper abdomen of *O. brumata* are blunt and four to seven pointed. The eggs hatch in early April and the larvae, which feed until late May, are somewhat similar to the larvae of *Erannis defoliaria*, but the yellow area on the sides of the first six abdominal segments is confined to the prespiracular region.

Erannis defoliaria.—This species is usually considered within this group to be next to the Winter Moth in abundance, but in 1952 54 relatively few larvae were seen on unsprayed fruit trees in the East Malling area. The female moth, nearly 2 cm. in length, is a very striking insect. Most of the scales are jet black but these are interspersed with yellow or sometimes white scales to give a mottled appearance. The males are variable, the ground colour of the wings being buff to reddish fawn. On the forewings there is a lateral area which may be slightly darker or quite black, with a paler transverse band in its centre. The span of the forewings is nearly 40 mm. The eggs are laid in rough areas

of the bark ; the larvae hatch out in early April. They feed more openly than the Winter Moth and are readily disturbed, when they hang from a silken thread with the thorax held back at an angle to the abdomen. They may be identified by the continuous yellow area along the sides of abdominal segments one to six. They travel to the soil in early June, to form naked pupae, which appear to be capable of aestivation. When some were stored dry at laboratory temperatures until January, and then placed in moist peat in a cold insectary, moths emerged as late as March, some two months later than normal.

Phigalia pilosaria.—The conspicuous larva of this species has often been reported from fruit trees, though never in abundance. The male moth, less slender than others of the group, has a greyish pink abdomen. Its thorax has a large lappet. The forewings, spanning up to 50 mm., though usually grey flecked with black, are sometimes a uniform greyish black with blacker scales on the veins. The hindwings are a more uniform grey with a darker cross line, and the antennae are conspicuously ciliate. The female is greyish pink or sometimes quite black, the deeply divided overlapping scales on the dorsal surface giving the moth a hairy appearance. The large warty larva grows to some 45 mm. in length during April and May.

Erannis leucophaearia, *Apocheima hispidaria*, and *Theria rupicapraria* were all uncommon in the East Malling district in the years under consideration, and it was hence not possible to gain information on the biology of these species.

Importance and control

In orchards well sprayed with a pre-blossom application of an insecticide such as DDT, caterpillar damage is practically negligible. There is thus no evidence to suggest that caterpillars of any of these species hatching rather later than the Winter Moth (such as the March Moth) are not controlled by modern spray programmes. However, these insects persist in orchards which receive few or no sprays.

Acknowledgements

The writer wishes to thank Dr. A. M. Massee and other members of the Entomology Section for their help and advice throughout this work.

Summary

Some features of use in the identification of certain allies of the Winter Moth on fruit trees are described, with keys to the apterous females and larvae. Biological notes are given for the more important species.

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Appendix I

Key to the apterous females of 'Winter Moths' found on fruit trees

1.	Anal tuft prominent, composed of many hundreds of hairs	*Alsophila aescularia*
	Anal tuft, if any, of few hairs	2
2.	Body mottled jet black and yellow or white	*Erannis defoliaria*
	Body grey, brown, or if black not mottled	3

Fig. 2

Eggs of some Notodontoid moths (×35).
Top left, *Operophtera fagata*; centre, *Erannis progemmaria*; right, *Erannis aurantiaria*.
Bottom left, *Operophtera brumata*; centre, *Erannis defoliaria*; right, *Phigalia pilosaria*.

Fig. 3.

Egg band of *Alsophila aescularia*, with female in attendance (approx. ×2).

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3.	Tibiae markedly hairy	*Apocheima hispidaria*
	Tibiae clothed with scales, with at most only a few short hairs	4
4.	Front half of dorsal surface of abdomen clothed with bifid scales divided nearly to their base, thus apparently hairy; body copper and grey, or black	*Phigalia pilosaria*
	Front half of dorsal surface of abdomen clothed with scales, which if bifid are not divided beyond their middle; body various shades of brown and white	5
5.	Hindwings longer than forewings	*Erannis progemmaria*
	Hindwings shorter than forewings	6
6.	Forewings more than half length of body	7
	Forewings less than half length of body	8
7.	Tips of forewings rounded, present before 1st January	*Operophtera fagata*
	Tips of forewings square, present after 1st January	*Theria rupicapraria*
8.	Forewings very short; moth with small anal tuft of about 100 hairs	*Erannis leucophaearia*
	Forewings about one-fifth to two-fifths length of body; moth without anal tuft of hairs	9
9	Scales on dorsal surface of front half of abdomen blunt, brown and white, with from four to seven points	*Operophtera brumata*
	Scales on dorsal surface of front half of abdomen slender, brown, white, and yellow, with from two to four points	*Erannis aurantiaria*

Appendix II

Key to the principal full-grown Notodontoid larvae found on fruit trees

1.	Abdominal segment five with reduced prolegs	2
	Abdominal segment five with no prolegs	3
2.	Brown larva with lateral fleshy filaments on abdominal segments	*Campaea margaritata* (L.)
	Green larva	*Alsophila aescularia*
3.	Head bifid	4
	Head rounded	5
4.	Lateral processes on abdominal segment five	*Biston betularia* (L.)
	No processes on abdominal segment five, with longitudinal striping on the body	*Lycia hirtaria* (L.)
5.	Prominent warts all over body	6
	Pair of warts on ninth abdominal segment	*Colotois pennaria* (L.)
	Without warts on body	7
6.	Warts dispersed, large, with a prominent V-mark on abdomen segments 2 and 3	*Phigalia pilosaria*
	Warts dispersed, small, with no V-mark	*Apocheima hispidaria*
7.	Mid-dorsal line an ill-defined to very definite red	8
	Mid-dorsal line where present not red	9
8.	Body green, translucent, about 2 cm. when fully grown	*Chloroclystis rectangulata* (L.)
	Body opaque, ventral surface white, dorsal surface green, about 3 cm. in length when fully grown	*Oporinia dilutata* (Schiff.)
9.	Brown larva with yellow markings	10
	Grey, olive, green, or whitish larva	11
10.	Lateral yellow patches in the prespiracular area of first six abdominal segments	*Erannis aurantiaria*
	Continuous lateral yellow area from third thoracic to sixth abdominal segment	*Erannis defoliaria*
11.	Green larva, ventral surface whitish	*Theria rupicapraria*
	Ventral surface not white	12
12.	With white patch at spiracles. Colour olive green, grey, or white	*Erannis progemmaria*
	Spiracles not white	13
13.	Dorsal and subdorsal lines paired, colour from olive to very pale green	*Erannis leucophaearia*
	Pale green larva with dark dorsal and spiracular stripes, chitin black	*Operophtera fagata*
	Pale green larva with light dorsal and spiracular stripes, chitinous parts transparent or mottled grey in colour	*Operophtera brumata*

PLANT PROTECTIVE CHEMISTRY

SOME FIELD EXPERIMENTS UPON THE CONTROL OF CODLING MOTH, *ERNARMONIA POMONELLA* (L.), BY ORGANIC INSECTICIDES

By R. P. TEW and JOAN R. GROVES

Many attempts have been made to find a substitute for lead arsenate, which is commonly used for the control of the Codling Moth, *Ernarmonia pomonella* (L.), (=*Cydia pomonella* (L.)), on top fruit. Both inorganic (cryolite, calcium arsenate, zinc fluoroarsenate) and organic (nicotine, xanthone, phenothiazine) poisons were investigated without much success in the pre-DDT era and considerable effort was directed towards improving the effectiveness of lead arsenate itself by the use of adjuvants. Wherever it was tested against this pest, DDT was soon found to be most effective but to suffer from the serious drawback that its use was often followed by serious outbreaks of phytophagous mites. It is clear from a recent review of the use of lead arsenate and of DDT in orchards in many parts of the world (Brown, 1951) that neither chemical can be regarded as satisfactory. It was decided, therefore, to make a field comparison between these chemicals and a number of the more recently developed organic insecticides.

Field trial in 1951

The chemicals selected for field study in 1951 were aldrin, dieldrin, toxaphene, and 2-(1-methylheptyl)-4:6-dinitrophenyl crotonate (DNOPC). Aldrin, dieldrin, and toxaphene were considered worthy of test on grounds of general insecticidal potency and persistence ; there was also some evidence (Kirby and McKinlay, 1951) that they were somewhat toxic to summer eggs of the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch). At the same time it was considered worthwhile to include the dinitrophenol, DNOPC, which, in addition to being of value against Apple Scab and Apple Mildew, is markedly acaricidal (Lathrop and Hilborn, 1950). The trial was conducted on a mixed plot containing mature trees of the four varieties Cox's Orange Pippin, Bramley's Seedling, Worcester Pearmain, and Charles Ross, trees of the latter two varieties being used for records. The following treatments were replicated four times (twice on each variety) :

Chemical	*Concentration* (per cent)	*Formulation*
Lead arsenate	0·2	Commercially available powder.
DDT	0·1	Commercially available 20 per cent wettable powder.
DNOPC	0·05	Commercially available 25 per cent wettable powder.
Aldrin	0·05	These were formulated as emulsifiable concentrates using acetone (2 per cent) and a non-ionic surfactant (0·025 per cent).
Dieldrin	0·05	
Toxaphene	0·1	This was formulated as a solvent-free emulsifiable concentrate by melting with a non-ionic surfactant.

The sprays were applied on 9th July by twin-nozzle lances from a 175-gallon tractor-driven machine, in such a way that unrecorded trees acted as guards against spray-drift. Degree of control was assessed by recording the percentages of the total crops, both dropped and picked fruit, which showed larval damage. An analysis of variance was carried out on these results and the retransformed means are recorded in Table I.

To obtain an impression of the immediate effect of these sprays upon the Fruit Tree Red Spider Mite, an imprint record (Austin and Massee, 1947) was taken on 16th July from each pair of Worcester trees. Each sample comprised 48 leaves ; eggs and mites were counted separately and an analysis of variance carried out. Retransformed mean numbers of mites and eggs per leaf are given in Table II.

The results obtained provided very clear evidence of the toxicity of DDT to Codling Moth larvae ; at the relatively low level of incidence of attack which was recorded none of the other chemicals effected any significant improvement. The acaricidal activity of DNOPC was shown by the significantly lower population density of mites which resulted from its use.

TABLE I

PERCENTAGE OF CROP DAMAGED BY CODLING MOTH LARVAE IN 1951 TRIAL

Treatment	Crop damaged (per cent)
DDT, 0·1 per cent	3·9
Lead arsenate, 0·2 per cent	12·3
Toxaphene, 0·1 per cent	12·5
Dieldrin, 0·05 per cent	14·5
Unsprayed	16·3
DNOPC, 0·05 per cent	17·7
Aldrin, 0·05 per cent	18·3

Means within brackets do not differ significantly ($P=0·05$).

TABLE II

MEAN POPULATION DENSITIES OF FRUIT TREE RED SPIDER MITE 7 DAYS AFTER APPLICATION OF TREATMENTS IN 1951 TRIAL.

Treatment	Mean numbers per leaf	
	Mites	Eggs
Dieldrin, 0·05 per cent	274	187
DDT, 0·1 per cent	249	129
Aldrin, 0·05 per cent	229	105
Toxaphene, 0·1 per cent	183	122
Unsprayed	177	70
Lead arsenate, 0·2 per cent	132	71
DNOPC, 0·05 per cent	46	129

Means within brackets do not differ significantly ($P=0·05$).

Field trial in 1952

It was decided in 1952 to compare toxaphene, lead arsenate, and DDT on a site where a higher infestation of Codling Moth could be expected. To this end the trial was carried out on a plot of mature Cox's Orange Pippin trees on M.XII situated close to a packing-shed, from which source orchard infestation commonly occurs (Groves, 1952). There were four replicates of the following treatments : lead arsenate at 0·2 per cent, DDT at 0·1 per cent, toxaphene at 0·13 per cent, toxaphene at 0·1 per cent plus a sticker (PEPS) at 0·05 per cent, and an unsprayed control. Lead arsenate powder and a 20 per cent DDT wettable powder were again used, but a change was made in the formulation of toxaphene, the commercially available emulsifiable form which had been used with success in field experiments against the Summer Fruit Tortricid, *Adoxophyes orana* (F.R.) (Groves and Tew, 1953), being selected. An attempt was made to improve the performance of this chemical by the inclusion of a sticker (of the polyethylene polysulphide type), which had proved of some value in experiments using dinoseb against the winter egg of the Fruit Tree Red Spider Mite (Kirby, Tew and Gambrill, 1954).

The sprays were applied on 16th June, using a triple-nozzle lance from a power-operated 50-gallon machine in such a way that unrecorded trees acted as guards against spray-drift. Degree of control was again assessed by recording the percentage of the total crop damaged by larvae. An analysis of variance was carried out on the results and retransformed means are given in Table III.

Effects on the Fruit Tree Red Spider Mite were again assessed by an imprint record, but a month was allowed to elapse after the spraying. This record was taken on 18th July, the total numbers of mites and of eggs on 24 leaves from each tree being counted. Retransformed means per leaf from the analysis of variance to which these results were submitted are given in Table IV.

The anticipated higher level of attack was realized and as in 1951, only DDT gave any measure of control. In this trial DDT application was associated with very large increases of both mite and summer egg populations ; toxaphene was also associated with large increases and even lead arsenate plots showed significant, though smaller, increases. This was not recorded in 1951 when only one week elapsed between spraying and recording, but may well have been the situation later in the season.

TABLE III

PERCENTAGE OF CROP DAMAGED BY CODLING MOTH LARVAE IN 1952 TRIAL

Treatment	Crop damaged (per cent)
DDT, 0·1 per cent	21·0
Lead arsenate, 0·2 per cent	39·3
Unsprayed	48·0
Toxaphene, 0·1 per cent+PEPS, 0·05 per cent	48·6
Toxaphene, 0·13 per cent	53·8

Means within brackets do not differ significantly ($P=0·05$).

TABLE IV

MEAN POPULATION DENSITIES OF FRUIT TREE RED SPIDER MITE 32 DAYS AFTER APPLICATION OF TREATMENTS IN 1952 TRIAL

Treatment	Mean numbers per leaf	
	Mites	Eggs
Unsprayed	2	2
Lead arsenate, 0·2 per cent	6	13
Toxaphene, 0·13 per cent	13	56
Toxaphene, 0·1 per cent+PEPS, 0·5 per cent	18	80
DDT	24	89

Means within brackets do not differ significantly ($P=0·05$).

Summary

In field trials during two years in which single applications of lead arsenate, four chlorinated hydrocarbons (aldrin, dieldrin, toxaphene and DDT) and a general-purpose pesticide 2-(1-methylheptyl)-4 : 6-dinitrophenyl crotonate (DNOPC) were compared, only DDT significantly reduced damage due to Codling Moth larvae. In the 1951 trial DNOPC exhibited characteristic acaricidal action as regards the Fruit Tree Red Spider Mite. In the 1952 trial all three chemicals tested (lead arsenate, toxaphene and especially DDT) were associated with increased populations of this mite.

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THE FRUIT TREE RED SPIDER MITE, *METATETRANYCHUS ULMI* (KOCH): A FURTHER PILOT TRIAL IN THE FIELD OF TWO OVICIDES APPLIED TO APPLES AT PINK BUD

By R. P. TEW and R. G. GAMBRILL

The demonstration that certain chlorinated phenyl benzenesulphonates are toxic to winter eggs of the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch) (Kirby and Tew, 1953), led to a field trial (Kirby, Tew, and Gambrill, 1954) in which several pre-blossom treatments, based on the more promising members of this series of organic compounds, were compared with the control measure (DNC-petroleum) conventionally employed before bud burst against winter eggs. The present paper describes a similar experiment in which two ovicides, 4-chlorphenyl 4-chlorbenzenesulphonate (chlorfenson, CPCBS) and 4-chlorphenyl 4-chlorbenzyl sulphide (chlorbenside), usually applied post-blossom, were compared at the pink-bud stage of development.

Effects of 1953 trial

The N-S row of Worcester Pearmain trees on M.IX rootstocks which was used in the field experiment already reported (Kirby, Tew, and Gambrill, 1954) and which in the meantime had received no further sprays, was surveyed for winter egg density on 1st March, 1954, the following category system being used :—

0 complete absence of eggs,
1 presence of very few eggs,
2, 3, and 4 medium levels of egg-density,
5, 6, and 7 heavy levels of egg-density.

A pattern of winter egg density very similar to that found prior to the 1953 trial was revealed. Statistical analysis disclosed a similar residual effect from all of the 1953 chemical treatments and the following figures represent the retransformed mean categories per treatment (5 trees) :

G	C	F	A	B	D	E	H
4·2	4·0	4·0	3·6	3·6	3·6	3·6	2·2

Significant difference ($P=0·05$)$=1·0$.

(Treatments A–F were chlorinated phenyl benzenesulphonates, treatment G was DNC (0·1 per cent w/v) and petroleum oil (3 per cent w/v), and H was the unsprayed control.)

It is of interest to observe the relatively high levels of winter egg density reached upon trees which were virtually freed from the mite the previous spring, whereas upon the unsprayed controls which suffered severe bronzing during the summer of 1953, a significantly lower level of winter-egg density existed. The trees were not under sufficiently close study during the summer season to decide whether these results were due to an effect of the mite ovicides upon beneficial species, to migration from the heavily-populated control trees, or to some other cause.

1954 trial

The 1953 trial and other field observations having confirmed the ovicidal activity of these chemicals to the winter egg of the mite, the 1954 trial was designed to give a close comparison between chlorfenson, the one most widely used, and a new type, chlorbenside, having similar effects. Both chemicals were applied at the pink-bud stage at two concentrations (0·1 per cent and 0·05 per cent), making four treatments. Each treatment was replicated ten times and applied in a balanced fashion to the previous design of five blocks of eight treatments. This scheme prevented the inclusion of unsprayed controls, but these were considered unnecessary as the two ovicides were expected to give similar degrees of control.

Commercially available wettable powders were used, and the sprays were applied on 30th April, using a twin-nozzle lance working at 70–80 lb. pressure from a self-propelled 25-gallon machine. Screens were used to prevent spray drift. No other application of insecticide or of fungicide was made during the period concerned in this trial.

A mangling record was taken on 14th June, when no unhatched winter eggs could be found and laying of summer eggs had already begun. As anticipated, very few mites were present and it was necessary to take a 16-leaf sample from each tree. The mite densities were very similar to those which resulted at this stage in the 1953 trial from similar winter egg infestations.

Both 1953 and 1954 treatments were considered in the statistical analysis of the records, and adjusted means for mites and summer eggs are given in Table I.

TABLE I

MEAN POPULATION DENSITIES, PER 16 LEAVES, OF MITES AND SUMMER EGGS SIX WEEKS AFTER APPLICATION OF TREATMENTS

Treatment	Adjusted mean numbers per 16 leaves	
	Mites	Eggs
Chlorfenson at 0·1 per cent	2·7	5·7
Chlorfenson at 0·05 per cent	8·4	7·3
Chlorbenside at 0·1 per cent	3·4	2·8
Chlorbenside at 0·05 per cent	5·3	4·1

The mite data showed no significant difference between the two ovicides at either concentration, but the higher concentrations were significantly more effective ($P<0·01$). The summer egg data indicated a significant superiority of chlorbenside ($P<0·05$).

Summary

Two established summer ovicides, chlorfenson and chlorbenside, have been compared on apple trees in the field as pink-bud treatments for the control of the Fruit Tree Red Spider Mite up to the stage when the hatch of winter eggs was complete. Both chemicals proved effective but there were significantly fewer summer eggs where chlorbenside treatments had been applied.

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Part IV

BULLETINS FOR FRUITGROWERS

VIRUS-TESTED ROOTSTOCKS AND SCION VARIETIES AVAILABLE AT EAST MALLING RESEARCH STATION

By A. F. POSNETTE and T. N. HOBLYN

Certain virus diseases of fruit trees are prevalent in varieties that show no conspicuous symptoms. Apart from the mild effect on these tolerant varieties, serious consequences may follow the growing of a sensitive variety on an infected but tolerant rootstock, or an infected scion on a sensitive stock.

As more is known about the effect of these virus diseases on fruit trees, the importance of propagating from healthy stock becomes increasingly evident. It has been the policy of this Station for several years to select healthy plants on the basis of virus tests. Provided that these plants are good representatives of their variety, they are then used for the propagation of trees for our field experiments. Experience with virus-free clones has already shown the advantages that they offer firstly to the nurseryman, and ultimately to the fruitgrower. Besides the obvious improvement in ease of propagation and in growth, healthy plants are more uniform than those infected even with the so-called ' mild ' viruses.

A full account of the selection and testing of these clones appears on page 115 of this Report. The purpose of this note is to acquaint fruit propagators and growers with the material available to them. We aim to select virus-tested clones of the more important varieties and rootstocks of all the tree fruits, but clearly we cannot attempt to produce them all simultaneously with our limited nursery resources. We propose, therefore, to offer mother trees of a particular variety to our Members for three years in succession. After that, material will be available to them only in very small quantities.

We have started to distribute apple and cherry varieties, because virus-free rootstocks are available in quantity for these crops and research proceeded faster than on pears and plums. We expect, however, to be distributing material of the latter two crops in the near future.

The health of the mother trees after they leave us will be checked periodically as extensively as is found to be practicable, with the Member's consent. Our present information on natural spread of the viruses concerned leads us to expect that mother trees will remain healthy for many years. Some viruses, however, are known to spread naturally in orchards and we cannot therefore predict that spread will occur as rarely in other localities as it has in the past at East Malling.

Varieties of which virus-tested selections have been made are listed below.

Apple

Rootstocks	*Varieties*
MM.104	Tydeman's Late Orange M.121
MM.106	Laxton's Superb, M.122
MM.109	Lord Lambourne, M.123
MM.111	Cox's Orange Pippin, M.124
M.XXV	Laxton's Fortune, M.125
	Worcester Pearmain, M.126
	Bramley's Seedling, M.127
	Jonathan, M.128
	Tydeman's Early Worcester, M.129
	Howgate Wonder, M.130
	Wagener, M.131

CHERRY

Rootstock

F.12/1

Varieties

Early Rivers, M.501
Napoleon, M.502
Merton Heart, M.503
Merton Bigarreau, M.504
Merton Bounty, M.505
Merton Glory, M.506
Geante d'Hedelfingen, M.507
Amber (Kent Bigarreau,) M.508
Bigarreau Gaucher, M.509
Merton Favourite, M.510
Noir de Guben, M.511
Bradbourne Black, M.512
Merton Premier, M.513
Governor Wood, M.514
Frogmore, M.515

Rootstocks

The five apple rootstocks and F12/1 cherry are now generally available in the trade, as well as from the Station.

Apple varieties

M.121–M.124 were issued in 1955–56 and will be offered again this year. M.125–M.131 are being worked for distribution and it is hoped they will be available in 1956–57.

Cherry varieties

Trees of M.501–M.504 have been offered for three years, M.505–M.507 two years, and M.510 one year ; a very few only will be available in 1956-57. M.508 and M.509, offered for the first time last year, have been worked for distribution in larger numbers this year, together with M.511, M.512 and M.513. It is hoped to add Governor Wood (M.514) and Frogmore (M.515) in 1957.

Summary

A brief account is given of the scheme for producing mother trees of virus-tested selections of top fruits at East Malling, with a list of rootstocks and varieties of apples and cherries expected to be available to Members in 1956 and 1957.

PRODUCTION OF VIRUS-FREE STRAWBERRY RUNNERS*

By A. E. H. RUTTER

Experience over the last 25 years has shown that an essential part of strawberry growing is the production of virus-free strawberry runners ; for, so long as viruses are present in the plants, the full potential of the crop can never be realized. Strawberry varieties differ in their reaction to the presence of viruses within their cells. Some, like Royal Sovereign, are very sensitive and clearly show such leaf symptoms as yellow-edge and crinkle ; others, like Huxley, are tolerant of certain of the viruses and do not readily show visible leaf symptoms, though the growth and cropping of the plants may be reduced considerably. Only when infected plants are being grown side-by-side with virus-free plants can the checking effect of the viruses be fully appreciated (Fig. 1).

How then is it possible to ensure that our plants are virus-free ? Firstly, by always planting virus-free runners, and secondly, by preventing as far as possible the spread of viruses within the fruiting beds.

The Strawberry Aphid is the chief vector or carrier of the strawberry viruses, and spraying with an organophosphorus insecticide should help to check the spread of the viruses in a fruiting plantation. Because fruit size declines with age, the economic life of a strawberry plantation is seldom more than three or four years, and provided virus-free runners are planted and the plantation is regularly sprayed, a fair degree of freedom from virus is generally assured for this period.

Testing for virus status

It is now nearly 25 years since East Malling Research Station commenced work on strawberry viruses and on the raising of a virus-free clone (a race of plants vegetatively propagated from a single parent) of each of the more important commercial varieties. The initial stages in the process of raising these clones involves the collection of stocks from promising sources, and the selection of individual plants for virus testing.

Individuals are selected for vigour, freedom from virus symptoms and, if possible, freedom from disorders such as June yellows in Auchincruive Climax. These selected plants are then tested for their virus status by runner-grafting to the wild strawberry (*Fragaria vesca*) and Royal Sovereign, which together are sensitive to all the known strawberry viruses. Two runners are grafted by making a single cut in each stolon, fitting the two tongues together (Fig. 2a) and binding the graft with a piece of crêpe rubber bandage (Fig. 2b). The stolons unite after ten to twenty days, when the bandage can be removed and the graft inspected. If there are any viruses present in the plant under test, then they will pass through the grafts to the sensitive wild strawberry and Royal Sovereign plants and there cause leaf symptoms after a few weeks (Fig. 3). The wild strawberry and Royal Sovereign are here acting as indicator plants, revealing the presence of any virus in the apparently healthy plant under test.

Inactivation of viruses

Virus-free plants of some varieties have been found quickly, but with other varieties a long search through material from the British Isles and the Continent, employing a large number of runner-graft tests, has been necessary before virus-free plants have been discovered. In the case of several of the commercially important varieties, however, no virus-free plants could be found anywhere.

Research was then concentrated on possible methods of inactivating viruses within a strawberry plant, and after some preliminary tests a successful method of heat treatment has been evolved. Potted plants are put into an incubator (Fig. 4) and kept at 100° F. for periods of up to three weeks depending on the heat tolerance of the variety. A constant temperature is maintained by thermostatic control of tubular heaters in the base. Humidity is kept as low as possible to reduce damage by fungi, especially *Botrytis cinerea*. Not all the plants stand up to this severe heat treatment, but a certain percentage remain alive, and after a recovery period the plants are tested for their virus status by the runner-graft method already described. Heat treatment has proved successful for many varieties, the following being the more important commercially ; Madame Lefebvre, Perle de Prague, Huxley, Early Cambridge, Cambridge Rearguard (503), Cambridge Prizewinner (134), and Sir Joseph Paxton. Previously there were no known virus-free plants of these varieties. Further varieties, including new varieties received from the plant breeders, are being tested, and if necessary, heat-treated to ensure that virus-free clones are available commercially.

* Reprinted, with amendments, from *Worthing and West Sussex Growers' Magazine*, July, 1955, No. 7, pp. 269-70.

Distribution of virus-free plants

The final stages in the production of virus-free runners concern cropping tests and multiplication of the best selections for commercial circulation. The annual procedure for propagation and distribution of virus-free plants has been modified recently and therefore may be of interest to growers.

Each year one or two plants of a virus-free clone are planted for propagation under insect-proof conditions in a glasshouse at East Malling, and are re-tested by the runner-graft method. Up to 100 runners are produced of any one variety ; these are then passed to the Nuclear Stock Association Ltd., a non-profit-making Society sponsored by the National Farmers' Union and founded in 1954. In the autumn of 1955, virus-free plants of Cambridge Prizewinner (134), Cambridge Vigour (C.1), Cambridge Rearguard (503), Royal Sovereign, Huxley, Madame Lefebvre, Talisman, and Early Cambridge left East Malling to be grown under contract for the Association on isolated farms in Anglesey and Norfolk, where the Strawberry Aphid population is low ; some plants are also being grown under insect-proof conditions in gauze-houses in Kent. The resulting plants are termed Foundation Stock and, if passed after inspection by the N.A.A.S. officers, receive the Foundation Stock certificate. The Association then contracts with a number of selected growers, having an isolation of at least five miles from intensive strawberry-growing areas, for the multiplication of this Foundation Stock to Elite Stock. The resulting plants are inspected periodically and, if passed, receive the Elite Stock certificate ; they can then be sold by the Nuclear Stock Association as Elite Stock to Special Stock growers.

Special Stock growers, who must have an isolation of one mile from fruiting beds, may propagate Elite Stock for one year only before selling runners to commercial growers, who should only purchase plants that have been given the Special Stock certificate.

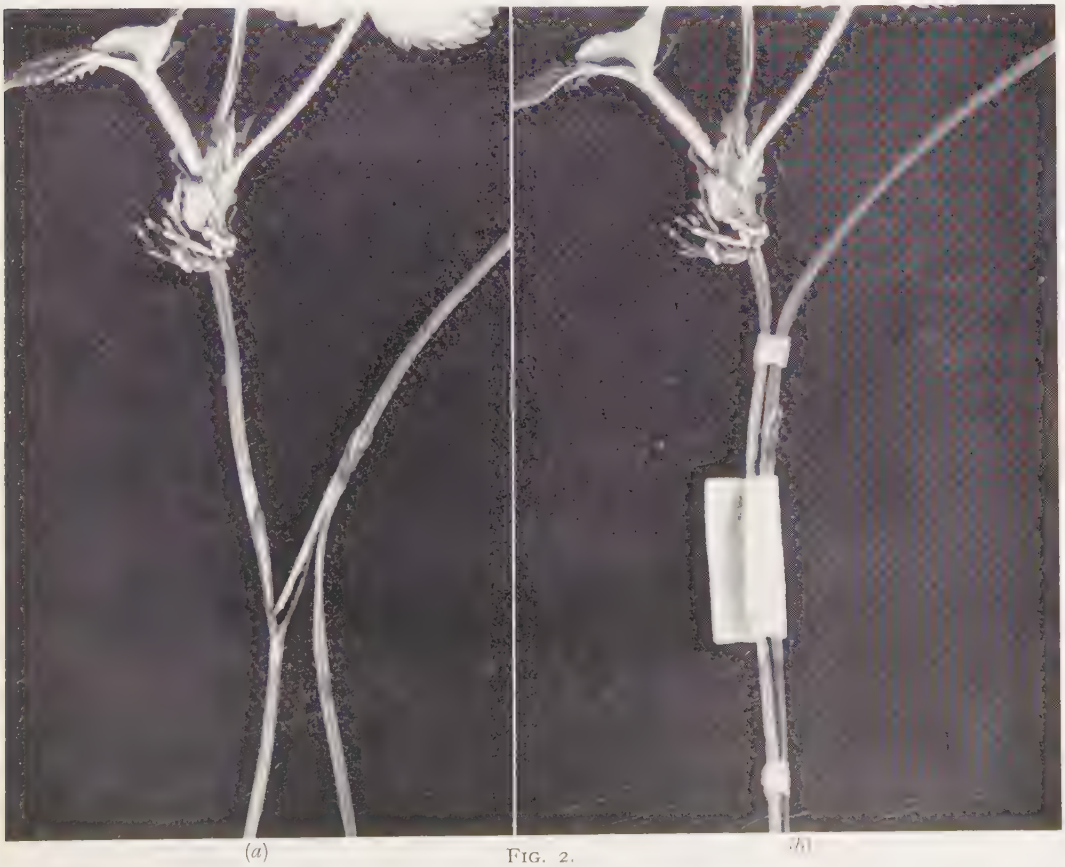
By maintaining this annual sequence, it is hoped that the strawberry grower will always be in a position to obtain runners for planting that are substantially free from virus infection.

Summary

The importance to strawberry growing of the production of virus-free strawberry runners is stressed. Descriptions are given of techniques employed in testing plants for their virus status and of the method of heat treatment used in the inactivation of viruses. The stages in the production and distribution of virus-free strawberry plants up to the time that they reach the grower are briefly outlined.

Fig. 1

Two Huxley strawberry plants of the same age. *Left.* Normal virus-free. *Right.* Virus-infected plant. Scale in inches.



(*a*) (*b*)

Fig. 2.

Runner-grafting technique. (*a*) A single cut has been made in each stolon and the two tongues are being fitted together. (*b*) The graft bound with a piece of crêpe rubber bandage.

FIG. 3.

Routine runner-graft test.
Test plant of Early Cambridge (*centre*) showing no visible virus symptoms. Wild strawberry (*Fragaria vesca*) (*left*) and Royal Sovereign (*right*), both showing virus symptoms following runner-grafting to the test plant.

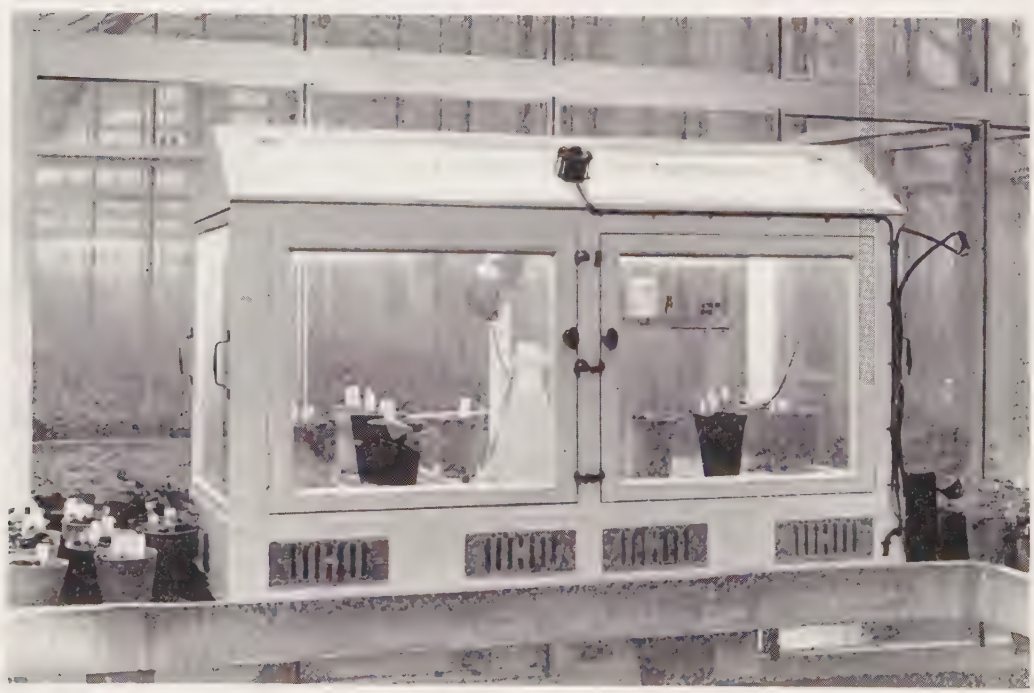


FIG. 4.

Incubator used for the inactivation of viruses within strawberry plants.

SOME PREDACIOUS INSECTS OF FRUIT TREES: LACEWINGS, LADYBIRDS AND HOVER FLIES

By ELSIE COLLYER

In previous articles the more important insect predators of the Fruit Tree Red Spider Mite and related mites have been described (*Rep. E. Malling Res. Sta. for 1953* (1954), 108 ; 1954 (1955), 155). It was pointed out that many of these species, although they feed readily on mites when these are abundant, are usually not in any way restricted to them as food ; they are general feeders and will attack mites or other insects that are available. Some of the predators that are to be described here are only incidental predators of mites, and favour larger prey such as aphids. It often happens that the adults are attracted into commercial apple orchards by local outbreaks of aphids ; later the aphids may become reduced by biological or chemical means, and the offspring of the predators, unable to fly away, feed on mites. Although these predators are often abundant, little is known of their effect on aphid populations. There are three main groups, lacewings, ladybirds, and hover flies.

Lacewings

Two main families of lacewings are to be found in orchards : the Chrysopidae, or green lacewings, and the Hemerobiidae or brown lacewings. A further family, the Coniopterygidae, a group of small lacewings (or dustywings) has already been described.

The green lacewings are sometimes called ' golden eyes ' on account of their characteristic eyes ; the adults have delicate green wings, long and slender antennae, and green bodies. Four species occur in orchards, two of them commonly : *Chrysopa carnea* Steph. is the most abundant, it is pale green and relatively small with a wing span of about one inch ; the other common species *Chrysopa septempunctata* is darker green in colour, and somewhat larger, the wing span being about one and a half inches. Adults are active in the orchard from April until late autumn, and are often common towards the end of the summer. Most of the species pass the winter within spherical or oval white cocoons that may be found in crevices of the bark, or in corrugated paper bands when these are placed around the tree trunks. The one exception is the species first mentioned, *Chrysopa carnea*, which hibernates as an adult insect. In the autumn adults of this species begin to lose their bright green colour and the wings become a pale red or reddish-brown ; they hibernate in this condition. When they emerge early in the spring they become green again and two complete generations are developed during the summer. Eggs of the green lacewings are very distinctive, they are a delicate shade of green, oval in shape, about one millimetre in length, and always borne at the end of slender, hair-like stalks. The stalked eggs are laid singly in many species, e.g., *C. carnea*, but in other species they are laid in groups, the bases of the stalks being fused together and bearing a bunch of eggs. Eggs are usually laid amongst or very near to aphid colonies.

Among the brown lacewings several species of *Hemerobius* are found on fruit trees, they are all very similar in general appearance and difficult to separate from each other. They are pale brown, speckled, and have a wing span of almost three-quarters of an inch. All the species overwinter in delicate white cocoons, and pass through two or three generations during the summer, so that all stages can be found throughout the season. The eggs are oval, laid flat on the surface of leaves or twigs, and are white or cream when laid, developing some colour just before hatching.

The immature stages of the lacewings are flattened, with very long piercing mouthparts and a tapering hind end. They vary in colour from yellow and orange to red or brown. Some of the brown lacewing larvae are relatively smooth, but the green lacewings have long spines arising from tubercles, on which a pile of debris (leaf hairs, sucked insects, etc.) is often carried. They have fairly long legs and move rapidly when searching for food. The adult lacewings are sometimes seen flying in the daytime, particularly the green lacewings, but principally they are nocturnal in habit and are often attracted to light at night.

Ladybirds

These insects are well-known as aphid feeders, and a number of species occur in orchards ; apart from the very small black species *Stethorus punctillum*, which feeds on mites, there are two large species that normally occur abundantly : the two-spot, and seven-spot ladybirds, *Adalia bipunctata* (L.) and *Coccinella septempunctata* L. respectively. These are bright orange in colour with black spots ; the immature stages are the black ' niggers ', completely unlike the adults in appearance, being black and hairy in *A. bipunctata*, and slate-blue with orange spots in *C. septempunctata*.

Ladybirds hibernate in the winter, often in aggregations, and emerge early in the spring on warm days. They soon disperse and may move considerable distances. The eggs are deep orange, oval in shape, and are laid standing on end in small batches on the bark and leaves. The first eggs are laid in May and June, and all stages can be found until the end of summer.

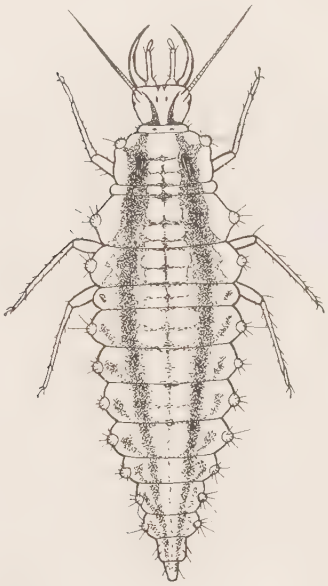


FIG. 1.
Fully-grown larva of *Chrysopa carnea* Steph. × 10.

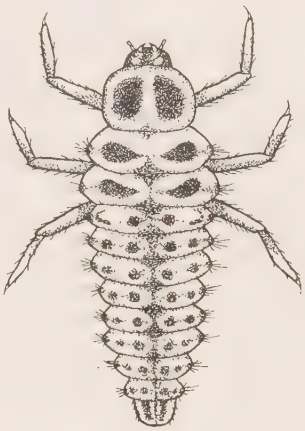


FIG. 2.
Ladybird larva. × 7.

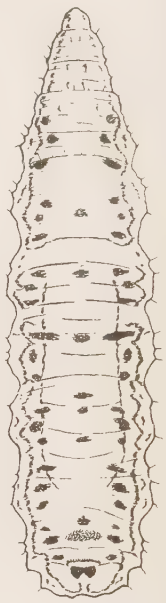


FIG. 3.
Syrphid larva. × 7.

Syrphids

These are brightly coloured flies, commonly called hover flies because of their habit of hovering motionless, usually above flowers to which they are attracted. Many are banded yellow and black and show a superficial resemblance to wasps. They form a large family, and the larvae exhibit very varied feeding habits ; among them is a group with predacious larvae, including the genus *Syrphus*. The larvae are soft-bodied slug-like creatures, with no legs, and are usually green or brown. The pointed head end of the larvae is mobile and is extended in search of prey which is then held high in the air while being sucked. The eggs are spindle-shaped, ribbed, and white in colour, and they are laid singly, flat on the surface of the leaves. These Syrphids overwinter either as larvae or pupae ; the pupa is formed within a brown hard barrel-shaped puparium, which often drops into the soil.

All three groups of insects occur commonly on a wide range of host plants ; they search for outbreaks of aphids for feeding, and almost invariably lay eggs near to such a source of food. The adult stage is in each case very active and may travel considerable distances. Whereas the adult lacewings and ladybirds are themselves predacious, the adult Syrphids feed on nectar and are therefore attracted to open flowers. Unlike the capsids, which are also plant-feeders, these insects in the immature stages at least are entirely predacious, and never actually feed on plant tissue. None of these insects is particularly connected with fruit trees or orchards, they are ubiquitous species that rest and reproduce where they find favourable conditions, probably, in particular, food supplies. They all prefer a concentrated food supply, such as that provided by aphid colonies, but once established in an orchard they may feed on a wide range of prey, including Woolly Aphid, caterpillars, Apple Sucker, and various mites. Thus a certain level of aphid infestation, either on the trees or the weeds beneath, can be of benefit in attracting these general predators.

Summary

Brief descriptions are given of the lacewings, ladybirds, and hover flies that occur in orchards, with notes on the pests that form their food.

THINNING APPLES BY THE LEAF-COUNT METHOD

By A. P. PRESTON

Thinning apples to either ' singles ' or ' doubles ', or spacing them to certain fixed distances apart along the branches, are common enough practices to fruit growers. Thinning apples by the leaf-count method, however, is less familiar and this bulletin considers the main results from a thinning trial where this method was used for many years on some mature trees of Duchess Favourite on M.IX. Since the leaves of a tree manufacture food, the ratio of leaves to fruits, especially in a year of heavy set, is a critical factor in determining fruit size at harvest ; thus the basic principle in fruit thinning is to increase this ratio.

The leaf-count method of thinning involves thinning the fruits, of course, not the leaves. The leaves on a tree, or on sample branches, are counted and the fruits are then thinned to leave one fruit for every so many leaves so as to give the desired ratio of fruit to leaf number. To ensure accuracy, the leaves were counted on each tree in the trial and the fruitlets thinned to one of three fruit/leaf ratios to determine the best one for the variety. The three degrees of thinning were :

1 fruit left for every 10 leaves on the tree (light thinning)
1 fruit left for every 20 leaves on the tree (medium thinning)
1 fruit left for every 30 leaves on the tree (heavy thinning)

Each degree of thinning was carried out on different trees either early, within 30 to 35 days from full bloom, or late, immediately after the June drop, about 74 days after full bloom.

When making the leaf-count, the very small primary spur leaves and the immature ones at the shoot tips were omitted. The fruit was then thinned by hand, to leave the appropriate number of fruits to leaves. The best placed fruit was left as is common in commercial practice when thinning. The trial began in 1945 when a very heavy set of fruit occurred on all trees, following a frost in 1944 when the blossoms were destroyed. The treatments affected the trees' behaviour in a number of interesting ways which will be considered separately.

Fruit bud formation and fruit set

The most important effect of time of thinning was its influence on fruit bud formation, the early thinned trees being much more regular in forming fruit buds than the late thinned ones. Of the three degrees of thinning, the more drastic ones, 1 fruit left for every 20 or 30 leaves, made the trees regular in fruit bud formation whereas light thinning, 1 fruit left for every 10 leaves, did not, and in fact differed very little from the unthinned trees in this respect. In degree, this light thinning was very similar to ' singling '. Over a five-year period in which fruit set was recorded thinning 1 fruit to 20 leaves gave the best set of fruit.

June drop

In some years, especially in ' off ' years when the unthinned and lightly thinned trees carried small crops, June drop was negligible but in other years it was appreciable and was recorded in detail. These records show that the drop from trees thinned early, leaving 1 fruit to 20 or 30 leaves, was too small to warrant delaying the thinning operation until after June drop had finished, but early thinning to 1 fruit for every 10 leaves resulted in some years in almost as heavy dropping as that from unthinned trees.

Fruit yield, size, and regularity of bearing

The general effect of the different degrees of thinning is clearly shown in the accompanying graph (Fig. 1). The more drastic degrees of thinning reduced the total crop but this was compensated for to some extent by a very marked increase in fruit size and red colour and equally important by regular bearing. The very heavy set of fruit in 1945 began a biennial bearing rhythm in the lightly thinned and unthinned trees that persisted until 1948 when it became less, but it increased in intensity again in 1951, which was another year of heavy fruit set. Trees thinned to 1 fruit to every 20 or 30 leaves did not show this biennial habit. Over the whole period of the trial, however, fruit thinning to 1 fruit to 20 leaves gave the most valuable crops since the more drastic thinning, 1 fruit to 30 leaves, depressed the crop unduly without any marked increase in fruit size, quality, or regularity of bearing. There was no difference in regularity of bearing between the different degrees of thinning when carried out early, but with the late thinned trees those that were more heavily thinned were more regular.

Fruit size records showed that unthinned trees carried very much smaller fruits than those under the more severe methods of thinning, except, of course, in ' off ' years when the light crops from the unthinned trees consisted of large fruits. In 1949, a year of severe summer drought, the yields from

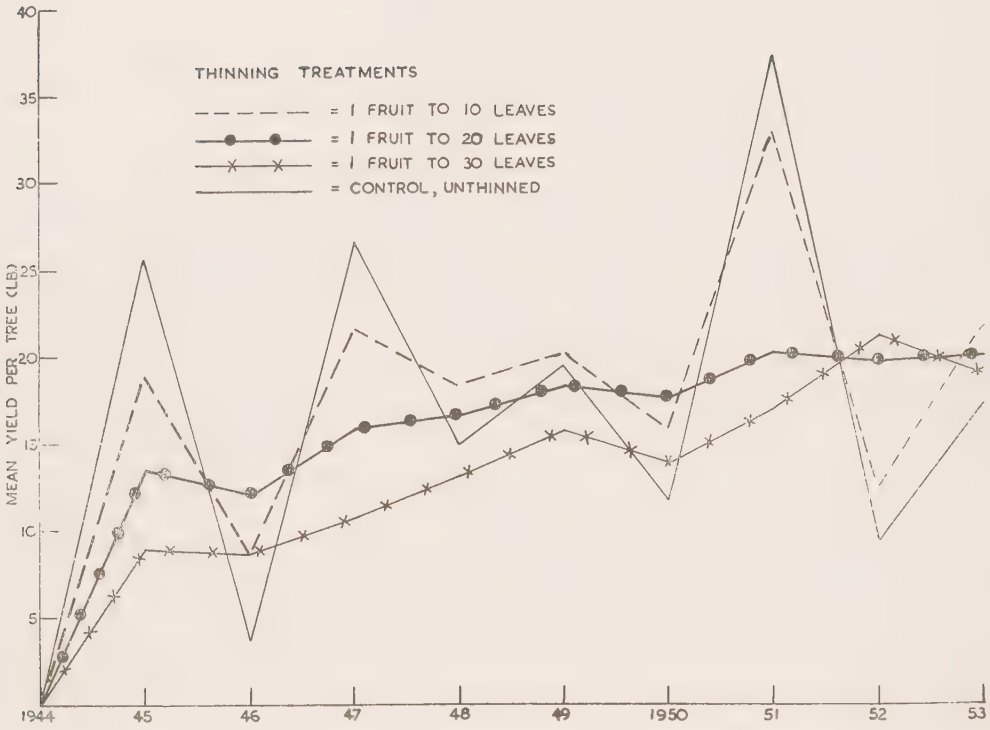


FIG. 1.

Effect of degree of thinning on fruit yield, and regularity of bearing. Note that in 1952 and 1953, when no thinning treatments were applied, there was a residual effect from the more severe thinning treatments.
(By courtesy of the Editors, *Journal of Horticultural Science*.)

thinned and unthinned trees did not differ very much but trees receiving the more drastic thinning treatments, 1 fruit to every 20 or 30 leaves, yielded larger sized fruits than did the unthinned trees. Time of thinning had surprisingly little effect upon fruit size and only in two years out of seven did early thinned trees yield larger fruits than late thinned ones.

Residual effect of thinning

The thinning treatments were applied in 1951 for the last time but records were made on tree behaviour for two seasons afterwards, without further thinning, until 1953 when the trees were grubbed. A residual effect of the thinning treatments can be seen in Fig. 1, for the years 1952 and 1953 ; fruit thinning to 1 fruit to 20 or 30 leaves in a year of heavy set (1951) resulted in regular crops of good-sized fruit during the following two years without any further thinning. This suggests that annual fruit thinning may not be necessary, but that it is probably essential in those years when a heavy fruit set occurs, to avoid the onset of irregular bearing.

Practical considerations

It is, of course, impracticable to count all the leaves on commercial bush apple trees before fruit thinning, but it is suggested that a leaf-count made upon a sample, representative branch on a few trees, together with a fruit-count on the same branches, will give a good idea of the existing fruit/leaf ratio and indicate the degree of thinning that may be necessary. Having obtained this information and thinned the sample branches the fruit so spaced may then be translated into distances apart and form a rational basis for fruit thinning instructions to the workers concerned.

The results of this trial are, of course, based on one variety and it is quite possible that varieties may differ for an optimum fruit/leaf ratio, but observations on Worcester Pearmain indicate that fruit thinning this variety to 1 fruit for every 20 leaves results in good sized fruit. With Cox's Orange Pippin, however, it seems that it may be best to wait until after the June drop before deciding upon thinning, for if this drop is heavy, thinning may not be necessary.

Summary

The results are summarized of a nine-year fruit thinning trial of the apple Duchess Favourite, where three degrees of thinning by the leaf-count method were carried out either early or late. The practical application of the leaf-count method of fruit thinning is discussed.

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